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FURTHER DEVELOPMENT OF AUTOMATED
GAT-1 PERFORMANCE MEASURES

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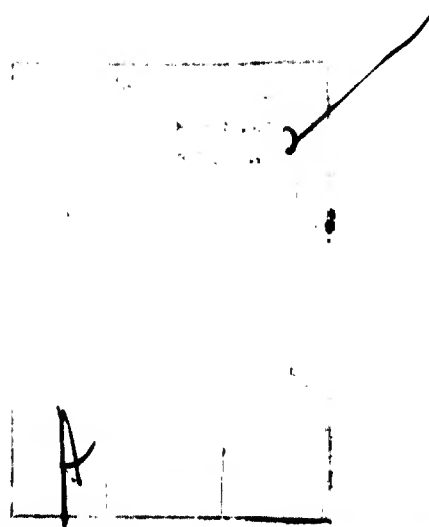
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Approved for publication.

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and standard deviations and further cross-tabulations to show which tasks and families of measurements are best at discriminating among pilots. Three different statistical methods were used to select a set of measurements from Experiment 1 and combine them into two new canonical variables, each a linear-weighted combination of the measurements in the set, to discriminate optimally among the three groups of subjects. Applying the canonical variables to the repeated measurements of Experiment 2 allowed several deductions about the best selection procedure to be made.

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PREFACE

This study represents a portion of the work being done under Project 1123, Flying Training Development, under the direction of Dr. William V. Hagin. This effort was documented under Task 112301, Development of Performance Measurement Techniques for Air Force Flying Training, and Work Unit 11230105, Further Development of Automated GAT-1 Performance Measures; Dr. Edward E. Eddowes Task Scientist and Contract Monitor.

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The authors are grateful to those who have substantially contributed to this project. Mr. Kenneth W. Gardiner provided valuable assistance in designing the flight tasks used in the experiments. Elizabeth Primrose and Cheryl Nemig obtained Qualified subjects for the experiment, ran them through the test series, and helped in the analysis of the results. Mr. A. F. Ferrara built up the computer interface and kept the GAT-1 flying throughout the study in spite of innumerable breakdowns.

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FURTHER DEVELOPMENT OF AUTOMATED GAT-1 PERFORMANCE MEASURES

I. INTRODUCTION

Pilot proficiency has previously been measured subjectively, and the resulting unreliability and lack of precision have made comparisons of pilot training programs a major problem. Consequently, various automated measurements have been sought by previous investigators. Early work by Krendel and McRuer (1960) showed no differences in single-axis compensatory tracking ability with pilot proficiency; the ultimate skill levels were achieved after a few practice sessions for all the subjects (Ss) involved. More recently, Garber and Krasnitskii (1968) found a small group of psychophysical variables that correlate with progress on initial flight training. Goebel, Baum, and Hagin (1971) found that several performance measures obtained from undergraduate pilots' first few hours of training time in a GAT-1 correlated with future performance. Their test battery included a number of tasks and a variety of measurements on each task.

This report describes a reanalysis and expanded study of the statistical approach of Hill and Goebel (1971) which selected test measurement that discriminated among changing pilot skills over the first 100 hours of flight training. The experimental system for generating these measurements consisted of a GAT-1 trainer interfaced to a small on-line computer. Performance measurements were based on 16 flight variables of the GAT-1 which were continuously monitored during ten simulated flight tasks. Basic performance measures consisting of means and standard deviations of selected flight variables and correlations between pairs of variables during each task were developed. It was believed that in sufficiently complex simulated flights, the Ss' differing abilities to divide their attention, and hold a number of variables constant could be used to measure their different skill levels based on their different amounts of flying experience.

Since compensatory tracking affords stable measurements of human performance, especially in the crossover region (McRuer, Graham, Krendell, & Resner, 1965), and can provide a number of models of pilot performance, a tracking task was included into Experiment 1. It was expected that two-dimensional tracking in the GAT-1, with its dependencies on several flight variables, would provide better discrimination of pilots on the basis of their experience than the single-variable tracking using a joystick often used in studies of psychomotor performance in the laboratory.

The two-dimensional tracking tasks (roll and pitch tracking) produced a surprisingly large number of measurements that separated the three experience groups of pilots studied in the previous Hill and Goebel (1971) research. Since the pilot-vehicle describing functions from the roll-tracking portion of the roll and pitch tracking task accounted for such a large number of discriminating tracking measurements, an assortment of new tracking tasks involving roll tracking was explored in the present experiment. One-, two-, and three-dimensional tracking tasks were included in the second experiment, as were variations in the amplitude and band-width of the roll command signal. Tracking tasks, based on the new flight variables, yaw, altitude, and ground position, also were included.

The types of measurements derived from the tracked variables were greatly expanded in Experiment 2. A frequency analysis of the coupling between variables in multicoordinate tracking tasks (cross-frequency analysis) was devised. A remnant analysis was included to determine smoothness of an individual S's internally generated response in carrying out a task. Several variables were derived from the describing function by fitting different constants and the simple crossover model of McRuer et al. (1965) to the individual S's data. Estimates of pilot gain, crossover, and equivalent time delay were obtained from the describing function. Similar measures were derived from the cross-frequency and remnant analysis. These new tasks and new families of measurements resulted in an increase in the number of measurements per S from 326 to 2,436.

Because of an error in the calculation of describing functions of the previous study (Hill & Goebel, 1971), this report includes a complete reanalysis of the previous data with corrected describing functions. Because of this change, and an additional error found in the multivariate discriminate analysis (the previous stepwise analysis was not terminated early enough in the step-by-step procedure), the corrected description of the previous study presented in this report as Experiment 1 should be considered a replacement for the entire previous report (Hill & Goebel, 1971).

II. EXPERIMENT I

Background

The describing functions of the previous study were not correct because the command signal used for the calculation of the S 's response was 90° out of phase. This problem was corrected by using the function $X(g + 1) - 1$, where g is the previous gain and X is the ratio of the correct command signal to the previous command signal. During this recalculation, several new variables were derived from the old data to make the old data comparable with the data of the new experiment. The variables added are given below and the calculations for obtaining them are described in Appendix A:

- Gains measured in decibels
- High frequency gain
- High frequency crossover
- High frequency phase
- Low frequency gain
- Low frequency crossover
- Low frequency phase
- Equivalent time delay

The second problem with the previous data analysis was that no limit for terminating the multivariate discriminant analysis was placed on the step-by-step procedure. The previous analysis terminated itself after 27 steps, ideally separating the three groups of ten S s. This, of course, represents a perfectly solvable problem and a statistical procedure is not necessary to solve it; 27 linear equations in 27 unknowns is a straightforward problem of algebra. The multivariate analyses were repeated using a realistic limit¹ to determine if an added variable in the analysis significantly contributed to the separation of the groups. When no additional variables were found that met this criterion, the analysis was terminated automatically.

Method

Apparatus. An existing interface between a link General Aviation Trainer (GAT-1) and a LINC-8 computer system (described by Hill, Gardiner, & Bliss, 1969) was enlarged to permit continuous monitoring of eight flight variables (airspeed, altitude, climb, roll, pitch, heading, glideslope, and localizer) and to allow the computer to supply signals to two GAT-1 variables (roll and pitch) for tracking tasks. Computer processing of the data to provide usable output was divided into two stages because of the limited memory size and computational power of the LINC-8 computer. The LINC-8 was used to accumulate simple sums, cross products, and Fourier sums; and to generate the sums of sines command signals on line. The time scale for these accumulations was based on a 15-Hz clock.² The variables were sampled, and sum, products, and command signals were updated every 1/15 second. The sums output from the LINC-8 recorded on paper tape at the end of the test runs were further processed by formula translation (FORTRAN) programs to calculate the means, standard deviations, correlation coefficients, and gains and the phase shifts for the tracking tasks.

Three hundred and twenty six individual test measurements were made for each S over the four-task test series. Many measurements had the same name but were measured in different tasks. Consequently, a numbering system was used to identify each of them. The numbering system is given in Appendix B by numbers placed to the right of the computer printout in the same relative positions as the values of the measurements.

Subjects. Thirty S s (three groups of ten) were selected on the basis of their flying experience and were run through the test series. Subjects in the beginner (B) group had little or no flying experience (less than ten hours); S s in the intermediate (I) group had moderate experience (25 to 50 hours); and S s in the

¹ A description of the program BMD07M, including a description of the step-by-step calculations performed, is given in References 7. The F-to-enter and F-to-delete levels were set to 2.5, and the tolerance level was set to 0.0001 for all computations reported.

² A stable clock was obtained by dividing the 60-Hz line frequency by 4.

advanced (A) group had extensive experience (more than 100 hours) and, in addition, had logged 20 or more hours in the previous six months. The majority (approximately 80 percent) of the Ss had 1-1/2 hours of experience in the GAT-1 trainer from a previous flight test. Many Ss, especially the advanced pilots, volunteered for the tests; others were obtained by offering them \$5.00 for a 2-1/2 hour session.

Procedure. A pre-test pilot familiarization period and four simulated flight tasks were selected for the experiment. They are described as follows.

Pilot Familiarization

Each S was asked to perform the following series of maneuvers to become accustomed to the GAT-1 and its flight characteristics prior to his attempting the experimental test tasks:

- (1) A takeoff and climb to 1000 ft heading due east.
- (2) A 180° left standard rate level turn in 1 minute.
- (3) A 180° right standard rate level turn in 1 minute.
- (4) A 500 ft climb at 500 ft/minute.
- (5) A power change to 1800 rpm and back to 2400 rpm.
- (6) A 500 ft descent at 500 ft/minute while keeping airspeed at 100 mph.
- (7) A level flight while switching on half flaps and then full flaps and maintaining altitude at 1000 ft.

This familiarization procedure took from 15 to 30 minutes, depending on the S. More warming-up time was spent with the B group than with the I or A groups. If a S did not reasonably complete one of the warm-up maneuvers, he was given a second opportunity before going on to the next.

Simulated Flight Tasks

(1) Task I—Roll and Pitch Tracking.

In this test the S was instructed to hold altitude at 1000 ft and heading at 90° (due east) while maintaining level flight with a power setting of 2400 rpm. He was told that a simulated rough air would make the trainer pitch and roll slowly and that he was to maintain altitude and heading as well as possible during the test run.

This test was basically a two-coordinate compensatory tracking task with sum-of-sine-wave command signals introduced into the roll and pitch axes to simulate rough air. The amplitudes of the individual command frequencies are given in Tables 1 and 2. In addition to the means, standard deviations, and correlations among the six monitored variables, the gain and phase of the pilot-vehicle describing function for both roll and pitch tracking were recorded.

Table 1. Amplitudes of the Roll Command Frequencies (Tasks I, II)

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
1	0.002	121.42
5	0.010	24.27
15	0.029	8.36
29	0.057	4.26
64	0.125	1.94
98	0.191	1.27
157	0.307	0.79
239	0.467	0.52

Table 2. Amplitudes of the Pitch Command
Frequencies (Tasks I, II)

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
2	0.004	30.05
7	0.014	8.57
14	0.027	4.44
27	0.053	2.27
59	0.115	1.04
81	0.158	0.76
145	0.283	0.42
274	0.535	0.22

A long warm-up³ time (34.2 seconds) was provided in this test to allow the *S* to adapt to the command signals that started abruptly with the onset of the run. During the remainder of the test (545 seconds) the *S*'s performance was continuously monitored. The six flight variables monitored in this test are listed in the computer printout shown in Appendix B under the analysis entitled, "Roll and Pitch Tracking."

(2) Task II—Roll and Pitch Tracking with Power Changes.

Task II was identical to Task I except that the *S* was additionally required to perform the series of power changes according to the schedule shown in Table 3. As in Task I the *S* first set up the trainer with proper altitude (1000 ft), heading (90°), and power (2400 rpm). Then he set the minute hand of the aircraft clock to between 1 and 2 minutes before the hour and continued to hold heading and altitude. When the time reached 0 minutes and 0 seconds, the *S* called "Mark" to the experimenter (*E*), who started the computer. The variables measured in Task II are shown in Appendix B under the analysis entitled, "Roll and Pitch Tracking with Power Changes."

Table 3. Sequence of
Power Changes for Task II

Time after Start (min)	Power (RPM)
1	2000
3	2600
5	2000
7	2600
9	2400

(3) Task III—Flight Profile.

This test task consisted of five short (2 to 3 minute) maneuvers performed in quick succession. The sequence of maneuvers is shown in Table 4. The *S* set up the clock as in Task II and called "Mark" at the beginning of the first maneuver (time 0) and at the beginning of the other maneuvers, as indicated in Table 4. When *E* heard "Mark" he started the computer monitor. The *S* was monitored for only the first 75 percent (approximately) of each maneuver, to keep the mean flight measurements from being biased if *S* completed the maneuver too quickly and to allow *E* time for entering commands at the teletype to set up for the next maneuver.

³The warm-up time was a time before the *S*'s performance was monitored, during which the LINC-8 generated the sum-of-sines command signals.

Table 4. Sequence of Events in the Flight Profile (Task III)

Maneuver Monitoring Duration (s)	GAT-1 Time (min)	Subtasks
Pretest		Hold altitude at 500 ft Hold heading at 90° Hold power at 2400 rpm
A. Climb - 95	0	Call "Mark" Change power to 2600 rpm Climb at 500 ft/min to 1500 ft
B. Right turn - 95	2-1/2	Call "Mark" Start right standard 360° turn Hold altitude of 1500 ft Hold airspeed of 110 mph
C. Slow flight - 145	5	Call "Mark" Reduce speed to 80 mph Hold altitude at 1500 ft Hold heading at 90°
D. Descending turn - 85	8	Call "Mark" Switch on half flaps Lower power to 1200 rpm Start left standard 360° turn Descend at 500 ft/min to 500 ft
E. Descent - 85	10	Call "Mark" Switch on full flaps Raise power to 2500 rpm Descend at 250 ft/min to ground Hold heading at 90°

The flight variables monitored and the output in each of the five maneuvers are given in Appendix B. No command signals were generated by the computer for the flight profile, but the rough air (internally generated by the GAT-1) was kept at its maximum value for the duration of the test.

(4) Task IV-ILS Landing Approach

In this final task *S* was instructed to climb to 2300 ft with power at 2400 rpm and a heading of 288° and fly toward the simulated airport at Seaport Beach. In addition to the instrument heading, a visual airport reference was used consisting of a piece of paper pinned to the cloth drape surrounding the trainer at a compass heading of 288°. The GAT-1 position plotter was used to position the trainer approximately 12 miles from the airport, directly on the approach beam. As the *S* flew into the glide slope beam and the glide slope needle crossed zero, he was instructed to call "Mark" to *E* and to begin descending at 100 mph, while keeping the glide slope and localizer needles crossed.

Since many of the *Ss* had never flown an instrument landing system (ILS) approach, even many of the *Ss* in the *A* group, a warm-up was given before the monitored test. The warm-up consisted of placing an *S* on the localizer beam before he started climbing to 2300 ft and letting him follow the beam while climbing, and then again while descending several hundred feet on the beam after the glide slope had been intercepted. During the warm-up period *E* gave *S* verbal help to keep him on the beam and suggested the strategy for returning to the beam if he drifted off. After this warm-up, the data run began, and the variables given in Appendix B were monitored.

In each of the monitored runs, for each of the simulated flight tasks described above, all the unchanging flight variables were monitored, but the remaining variables were not. For example, in a descending turn, altitude and heading were not monitored, but airspeed, rate of descent, roll angle, and pitch angle were monitored.

Determination of Discriminative Efficiency of Test Measures. A one-way analysis of variance was performed on each of the 326 sets of test measurements to determine the ability of each measure to distinguish independently among the beginning (B), intermediate (I), and advanced (A) groups of Ss. This use of the analysis of variance statistic is not in accordance with standard practices in psychological research and is in error judged by conventional criteria. The rationale for this nonstandard use of analysis of variance is presented subsequently and may be evaluated best in view of the specific requirements of the study. The distribution of the F values obtained from these analyses is shown in Table 5. In terms of the number of test variables with an F value greater than the limit shown and less than the next higher limit shown. The 50 measures with which it was possible to reject the null hypothesis for the three groups of Ss at the 5-percent level (F greater than 3.35) are shown in Table 6, together with the significance level achieved. In addition, Table 6 gives the mean of the measure for each group, the mean over all three groups, and the standard deviation over all three groups. The 50 statistically significant variables have been marked in the annotated final analysis printout of Appendix B so that they may be easily identified by name.

**Table 5. Distribution
of F Values for
Experiment 1**

F Limits	Significance	Variables
0	0.50	157
1.0		44
1.5		28
2.0		27
2.5	0.10	15
3.0		5
3.35	0.05	14
4.24	0.025	18
5.49	0.01	4
6.49	0.005	3
7.81	0.002	3
8.81	0.001	8
Total		326

To determine which of the four flight tests and which of the generic types of variables measured in the tests contributed most to differentiation, the summary shown in Table 7 was made. Of the four tasks, Tasks I through III contributed high proportions of significant variables (based on the number significant divided by the total number available from each task). Only 9 percent of the Task IV variables were significant. Since all the tasks contributed measures which discriminated among the B, I and A groups, it appears that a group of tests requiring several different skills and types of coordination, should be used to differentiate between the skill levels of pilots, rather than only one test.

Of the four types of measurements made in the tasks (means, standard deviations, correlations, and tracking parameters), the standard deviations produced the highest proportion (32 percent) of the significant differences between Ss. The tracking measurements were second best (after standard deviations) in ability to separate the groups of Ss, with 18 percent of them being significant. A breakdown of the tracking measures into those obtained in roll and pitch tracking, also given in Table 7, shows that almost all the significant tracking measures were obtained from roll-tracking gains. In fact, roll tracking was the most efficient task for generating significant measures with 34 percent of those measured significant at the 5 percent level. The most efficient variables of all were the roll gains, with 19 of the 32 measures (59 percent) statistically significant.

Table 6

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 1

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
22	4.34	.025	.015160	.080270	-.039740	.018563	.091176
27	4.02	.050	.016330	.077060	-.037080	.018770	.090022
32	3.64	.050	23.504	33.332	50.193	35.176	22.365
35	5.51	.010	1.186	1.637	2.083	1.636	.604
36	9.92	.001	.655200	.922570	1.190650	.922807	.268851
37	9.48	.001	.412370	.549650	.712370	.558170	.154228
38	4.81	.025	.325440	.414300	.466830	.402190	.103066
75	4.77	.025	2.948	2.249	1.530	2.242	1.026
77	4.86	.025	2.967	2.137	1.535	2.213	1.031
98	6.28	.010	7.133	8.072	14.731	9.072	5.226
100	13.48	.001	1.116	1.381	2.004	1.500	.393
101	10.71	.001	.594570	.851930	1.117000	.754500	.252398
102	4.59	.025	.423820	.534080	.628920	.528940	.151540
132	3.39	.050	433.525	441.600	462.225	445.783	25.413
138	4.00	.050	1.988	2.154	1.223	1.788	.785
140	3.79	.050	2.008	2.121	1.242	1.791	.776
156	4.93	.025	6.079	5.832	3.968	5.293	1.644
158	3.66	.050	186.621	192.167	126.796	168.528	59.913
160	3.99	.050	2.519	2.506	1.858	2.294	.599
172	4.99	.025	1409.	1437.	1489.	1445.	57.
173	3.63	.050	10.675	22.925	38.725	24.108	23.343
177	5.89	.010	7.767	6.214	4.511	6.164	2.123
181	4.34	.025	2.417	1.917	1.521	1.952	.682
184	5.26	.025	-.284770	.032620	.015760	-.078797	.246315
189	5.04	.025	-.454580	-.206610	-.225190	-.295460	.194462
199	3.40	.050	-.439.375	-.476.100	-.385.000	-.433.492	78.609
203	4.74	.025	156.234	174.024	96.985	142.414	58.564
205	5.13	.025	2.318	2.460	1.403	2.060	.801
206	4.97	.025	-.457200	-.696710	-.266030	-.473313	.306110
209	3.67	.050	-.298590	-.445960	-.192420	-.312323	.210122
210	5.19	.025	.577790	.725500	.571330	.624873	.121057
213	3.88	.050	-.173.125	-.169.725	-.211.400	-.184.750	37.173
241	7.27	.005	3.606	3.749	2.803	4.053	1.672
243	7.27	.005	5.642	3.933	2.829	4.135	1.662
245	4.66	.025	1.163600	.629900	.543600	.779033	.492202
268	4.53	.025	26.734	28.377	32.983	29.421	4.709
270	3.48	.050	9.372	12.919	14.394	12.228	4.373
271	3.83	.050	.610	2.930	6.136	3.225	4.481
272	8.49	.002	-.4.475	-1.091	1.328	-1.413	3.164
273	8.62	.002	-.8.392	-5.536	-3.103	-5.677	2.851
274	5.94	.010	-9.800	-8.087	-6.763	-8.217	1.976
278	8.40	.002	-5.514	-2.946	-.600	-3.020	2.681
284	7.61	.005	19.552	17.609	22.559	18.573	4.129
286	10.96	.001	.449	2.353	5.932	2.911	2.659
287	10.58	.001	-5.325	-1.683	.745	-2.088	2.971
288	5.03	.025	-8.120	-5.747	-4.218	-6.028	2.772
290	5.16	.025	22.231	24.000	27.863	24.698	4.011
293	9.23	.001	-5.814	-3.341	-1.344	-3.500	2.331
294	11.30	.001	.119520	.161580	.215440	.165513	.045221
322	3.64	.050	-165.987	-133.117	-145.311	-148.138	27.532

**Table 7. Breakdown of the Important Variables
in Experiment 1**

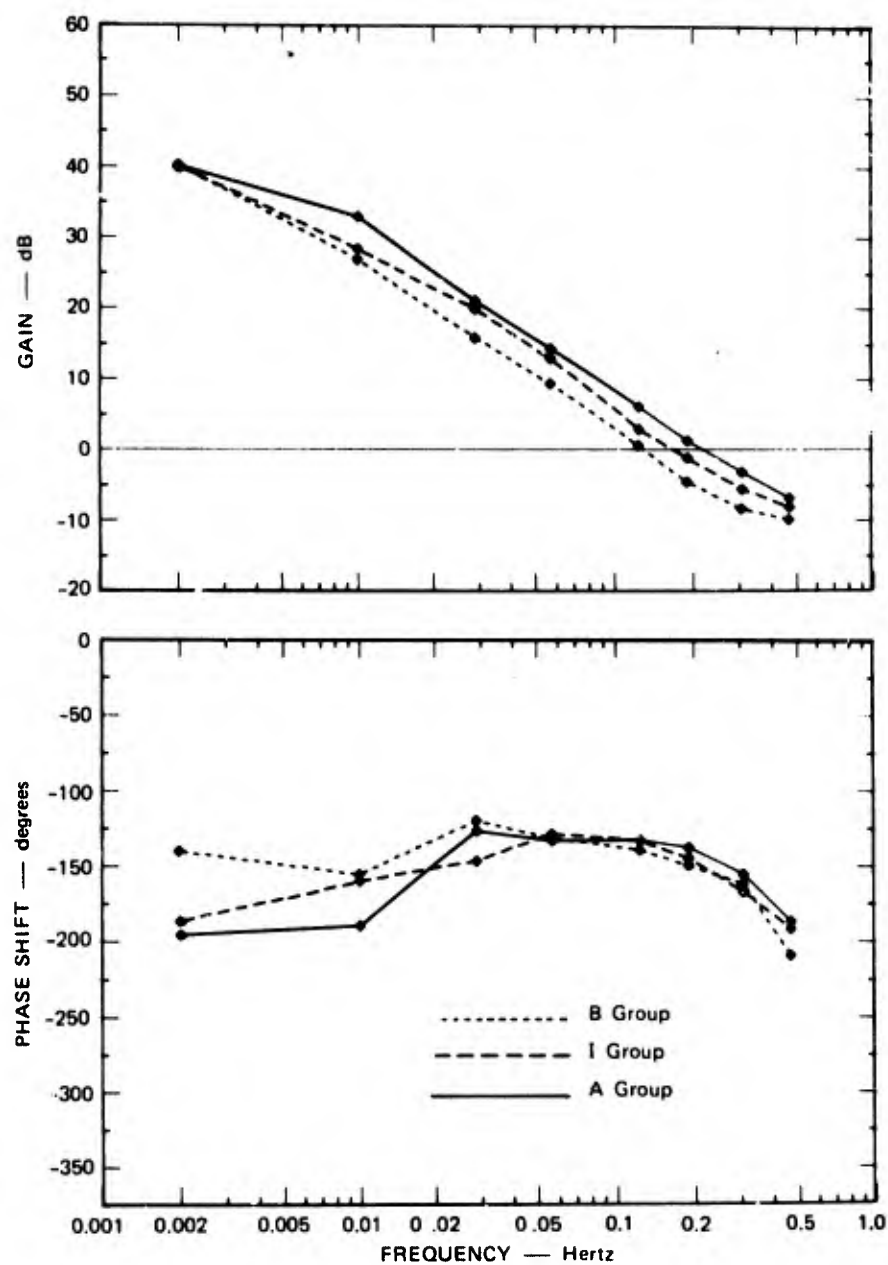
Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Task I	95	15	16
Task II	95	14	15
Task III	101	18	18
Task IV	35	3	9
Task Totals	326	50	
Means	44	5	11
Deviations	44	14	32
Correlations	102	7	7
Tracking	136	24	18
Variable Totals	326	50	
Roll gains	32	19	59
Roll phases	16	0	0
Roll derived	20	4	20
Pitch gains	32	0	0
Pitch phases	16	0	0
Pitch derived	20	1	5
Tracking Totals	136	24	

To understand better the differences among pilot groups evidenced in the pilot-vehicle describing functions (gains and phases), the describing functions for Task I shown in Figures 1 and 2 were studied. Where differences among groups exist, they were repeatable across the frequency spectrum. It is obvious from Figures 1 and 2 that the two derived variables, high and low frequency roll gain, contain all the useful gain information in the roll-describing function for separating groups. The low frequency roll gain differences were not significant because of their normal high variability, but differences in high frequency pitch phase were significant, with the B group showing greater phase shift (equivalently greater lag or reaction time) than the I or A groups.

The correlation coefficients were the least productive in showing significant differences among pilots. Since only 7 percent of them were significant at the 5 percent level, there is little evidence to indicate that they contribute to pilot skill differentiation and probably the correlations should be eliminated from the tests. On the other hand, only 5 percent of the pitch tracking measures were significant at the 5 percent level.

III. DISCRIMINANTS IDENTIFIED IN EXPERIMENT 1

One of the objectives of this study is to determine statistically the measures that can be used to define or evaluate pilot performance over the first 100 hours of training. The approach is to use a linearly weighted sum of automated performance measures (a discriminant or factor) that optimally differentiates among the three groups of Ss. Different means of obtaining this discriminant, using an analysis of variance and a "canned" stepwise multivariate discriminant analysis program, are described in this section. Three discriminant functions were obtained from the data pool of Experiment 1 for later application to the data pool of Experiment 2. This comparison allows estimation of the usefulness and reliability of the three methods for obtaining such discriminants described in this section.



SA-1676-2

FIGURE 1 PILOT-VEHICLE DESCRIBING FUNCTIONS FOR ROLL TRACKING IN TASK I

Each data point represents the average of ten subjects.

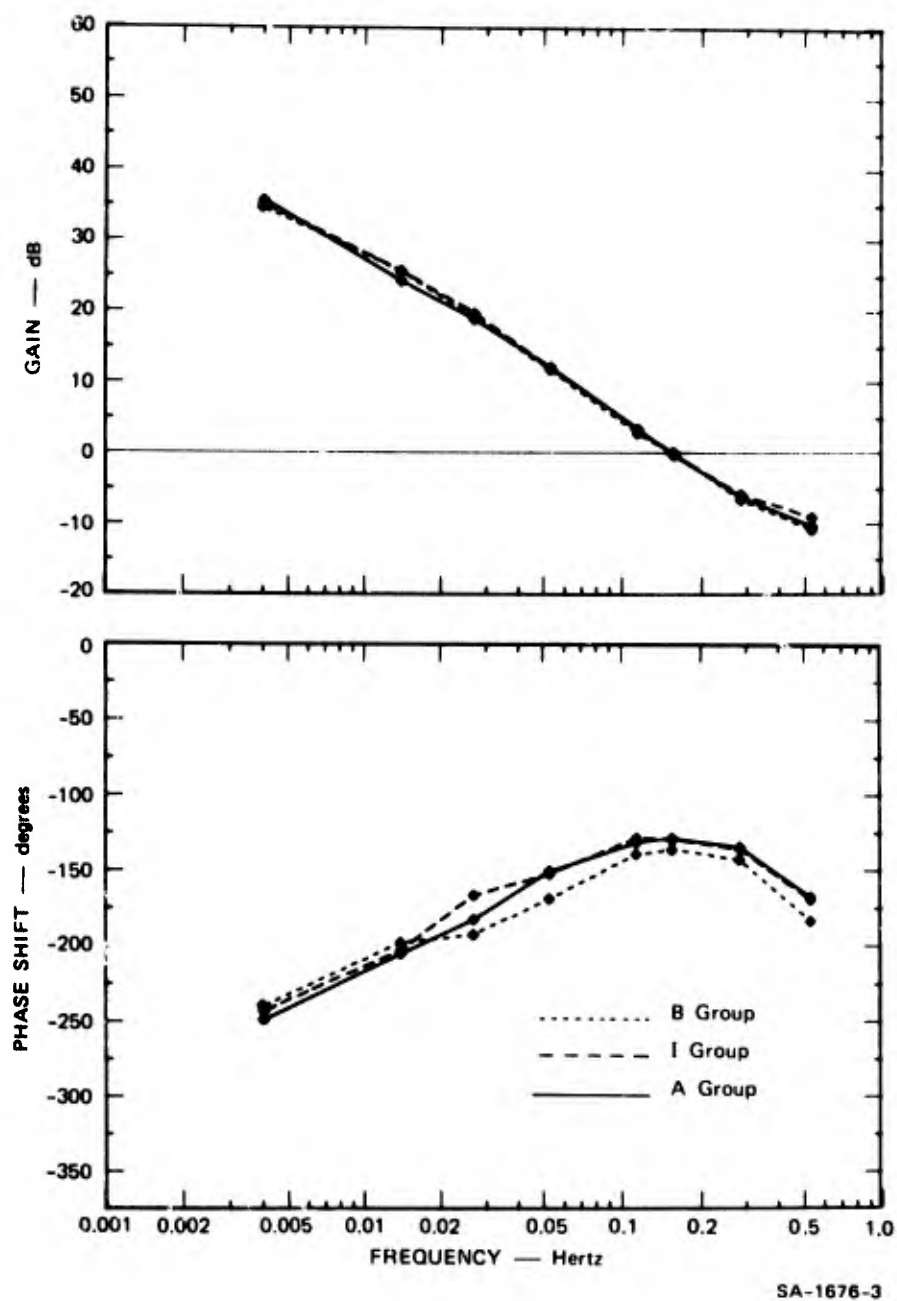


FIGURE 2 PILOT-VEHICLE DESCRIBING FUNCTIONS FOR PITCH TRACKING IN TASK I

Each data point represents the average of ten subjects.

AM Discriminant--Determined by Analysis of Variance Followed by Multivariate Discriminant Analysis

This two-stage method of determining a discriminant is based on an initial selection of measures using a one-way analysis of variance of each measure to determine its ability to separate correctly the different performance of the three groups of subjects. The resulting set of measures with an acceptable significance level is entered into a multivariate discriminant analysis program. The primary requirement for this two-stage method is to reduce the size of the set of measures set so all measures found to discriminate satisfactorily between B, I and A groups may be entered simultaneously into the analysis program. The multivariate program handles only 71 variables while in Experiment I there were 326 measures; consequently, the one-way analyses of variance were employed in identifying the "best" 71 of 326 for entry into the multiple discriminant analysis.

The distribution of F values shown in Table 5 was used to select the measures for input to the multivariate discrimination program. The set of measures with F values larger than a given F criterion consisted of two groups: those representing a real difference among the three experience level groups of pilot subjects, and those representing chance statistical fluctuations in the data. As the criterion F value is raised, fewer measures are included, but they are more likely to show real, repeatable differences. As the criterion is lowered, more variables are included, and a larger portion of them are variables significant by chance, showing differences among groups that will not be repeated in subsequent tests.

As a compromise between losing important variables and gaining variables significant only by chance, an F criterion of 2.5 was chosen. This value is achieved by 10 percent of the F s computed on samples drawn from the same population. A smaller F criterion would begin to include more false positives than positives, and a larger F criterion would eliminate too many discriminating variables. It can be seen that the analysis of variance statistic was used to aid decision making in a way other than that for which it is characteristically employed.

The 70 variables meeting the $F = 2.5$ criterion were entered into the stepwise multivariate discriminant analysis program, BMD07M, for the final selection of the most important flight variables. The program went through eight iterations before it stopped adding the variable with the highest F value at each step and recomputing the F values of the remaining unselected variables on the basis of the remaining pooled variance. In this way, eight of the 70 flight variables were selected by the program as being significant in discriminating among the three groups of pilots before the F level of the remaining variables became lower than that required for further computation. These final variables are listed in Table 8, with their initial F values [2 and 27 df (degrees of freedom)] and final F values [2 and 20 df] to test the null hypothesis among the three groups. The variables with the highest final F values are the most efficient in separating the three groups.

Table 8. AM Discriminant Summary

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
100	.125 Hz Roll, tracking gain, II	13.47	18.04	3.35	-.0179	1.50
153	Climb rate, III-B	2.60	8.12	.0199	-.00749	22.9
189	Pitch-altitude correlation, III-C	5.04	6.01	-.613	-5.67	-.295
210	Pitch-climb correlation, III-D	5.19	11.64	-8.10	-7.67	.624
225	Pitch-airspeed correlation, III-E	3.02	6.54	1.43	4.39	-.396
241	Roll standard deviation, IV	7.27	2.81	-.273	-.495	4.05
245	Localizer standard deviation, IV	4.65	6.41	-1.710	1.54	.774
313	.014 Hz Pitch tracking gain, II	3.33	11.23	-.235	.0867	25.6

After selecting the variables that best discriminate, the BMD07M program performed a coordinate rotation in eight-space to find new orthogonal variables (canonical variables or factors) that account for most of the dispersion (or variance) in the data. The value of the two canonical variables, C_1 and C_2 , for each pilot in the test series is given by:

$$C_1 = \sum_{j=1}^r u_j (x_j - \bar{x}_j) \quad (1)$$

$$C_2 = \sum_{j=1}^r v_j (x_j - \bar{x}_j) \quad (2)$$

Where r is the number of discriminating variables chosen (eight) in this case, u_j and v_j are the first and second canonical weighting coefficients, x_j is the value of the eight variables obtained for the given pilot, and \bar{x}_j is the grand mean for each of the discriminating variables. These data are given in Table 8. The individual values of the two canonical variables for the 30 pilots are shown in Figure 3, as determined from the coefficients and grand mean of Table 8 using Eqs. (1) and (2).

MM Discriminant—Determined by a Two-Stage Multivariate Discriminant Analysis

A second procedure for selecting the variables that best discriminate among the three groups of subjects is to break the 326 variables into groups of 71 or fewer variables and run the multivariate analysis to determine the variables significant in separating the three groups. This procedure may allow more interaction among variables in separating the groups than the previous method.

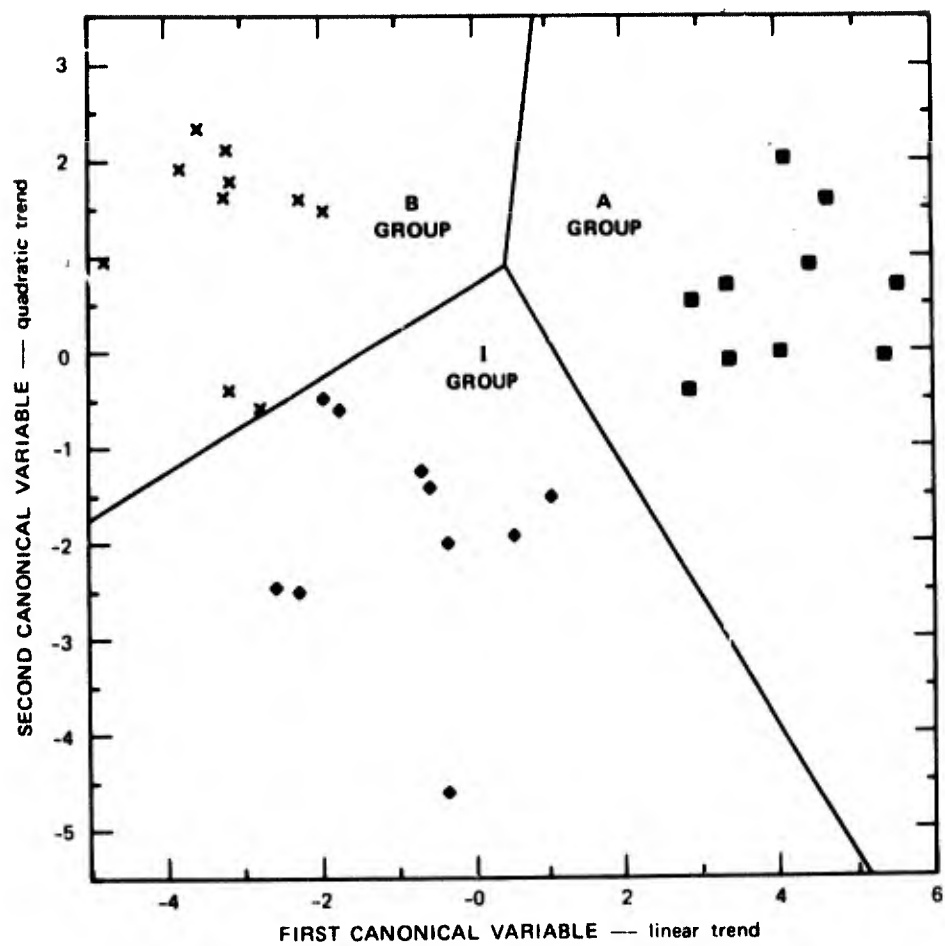
For this analysis the 326 variables were divided into the five groups shown in Table 9 and independently entered in the BMD07M multivariate discrimination program. The last group (Group 5) contained the derived tracking variables from Task I and II added in this reanalysis. These include the tracking gains measured in decibels and the constants fitted to the describing function.

The 47 selected test variables were again entered into a multivariate discriminant analysis for final selection. Fifteen of the 47 flight variables were selected before the statistical termination procedure was reached. These final variables are listed in Table 10 with their initial F values (2 and 27 df) and final F values (2 and 13 df). The individual values of the two canonical variables for each of the 30 Ss plotted using the coefficients and grand means of Table 10 and Eqs. (1) and (2) are shown in Figure 4.

Table 9. Summary of First Multivariate Analysis

Variable Group	Tasks	Number of Variables	Number of Significant Variables
1	I	65	6
2	II	65	17
3	III-A, III-B, III-C	67	11
4	III-D, III-E, IV	69	6
5	I, II	60	7
Total of all tasks		326	47

Close examination of the initial F values of the MM Discriminant of Table 10 reveals that more than half the variables chosen (8 out of 15) are not significant (5% test) in their ability to separate the three groups. Several variables even have F values close to 1.00 or below it, suggesting that they are but random variables contributing to the separation of the 30 particular Ss of the S pool but not to separation of experience groups in general.



SA-1676-4

FIGURE 3 CLUSTER PLOT OF THE AM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

Table 10. MM Discriminant Summary

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
22	Pitch-roll correlation, I	4.34	6.09	-12.7	-3.24	.0186
79	Climb-airspeed correlation, II	1.12	26.41	-30.4	-2.99	.180
98	.029 Hz Roll tracking gain, II	6.28	2.62	.353	.287	9.97
100	.125 Hz Roll tracking gain, II	13.47	35.79	8.15	1.01	1.50
153	Climb rate, III-B	2.60	27.95	.050	.007	22.9
183	Airspeed-altitude correlation, III-C	1.78	9.58	3.45	4.29	.108
196	Roll-yaw correlation, III-C	.85	6.61	-5.18	3.16	.950
205	Pitch standard dev., III-D	5.12	2.82	-.142	-1.35	2.06
210	Pitch-climb correlation, III-D	5.18	23.56	-23.6	-1.75	.625
225	Pitch-airspeed correlation, III-E	3.01	22.33	7.66	7.40	-.397
241	Roll standard deviation, IV	7.27	31.64	-1.83	.242	4.05
284	.029 Hz Roll tracking gain (db), II	7.61	7.37	-.620	-.876	18.6
291	Low frequency roll crossover, II	.50	7.38	-.580	.938	.647
307	Low frequency pitch phase I	.39	14.95	-.100	-.114	-195.
313	.014 Hz Pitch tracking gain (db), II	3.33	9.98	-.208	.265	25.6

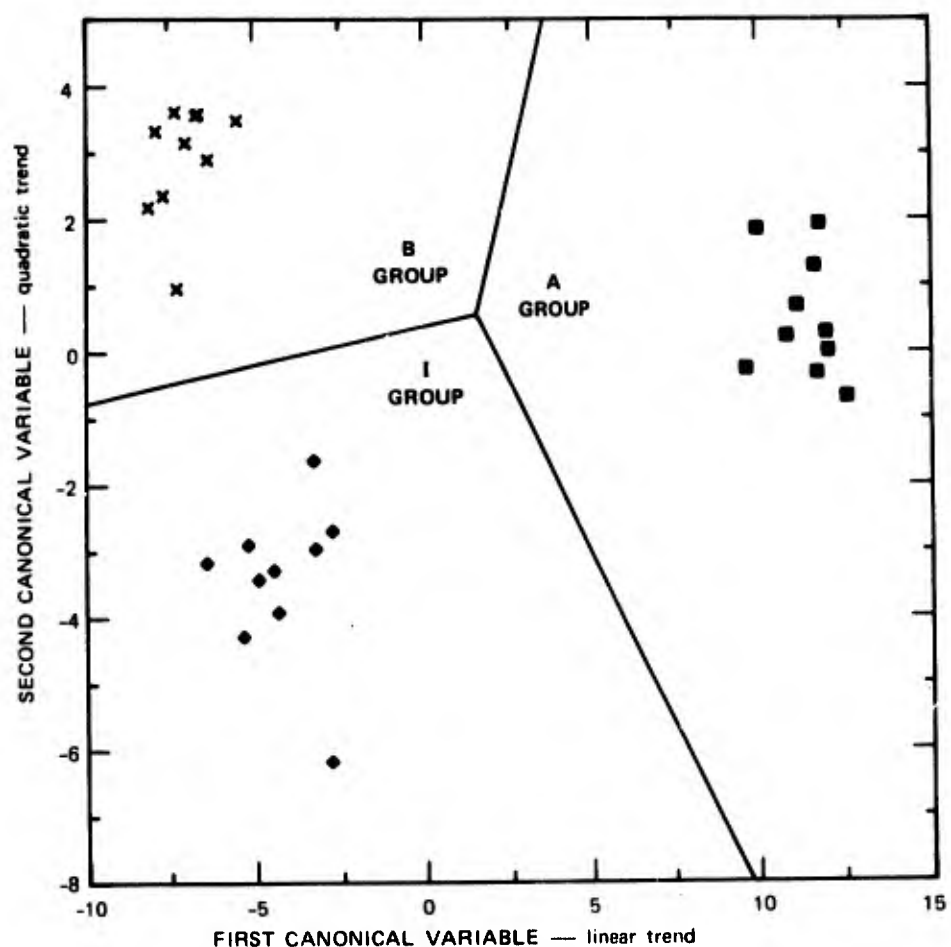


FIGURE 4 CLUSTER PLOT OF THE MM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

Because of the concern that the BMD07M program might not be capable of meaningful selection of variables from a large base (326) using only 27 df, some experiments with randomly generated variables were carried out.

Discriminants from Random Pools of Variables

Since no statistics are known on how well a stepwise multivariate discriminant analysis can be expected to select from pools of 60 to 70 variables to differentiate among three groups of 10 subjects, empirical data were obtained by running the program with random numbers. No statistic is available in the BMD07M program for determining the significance of the variable added at each step in further separating the groups. To solve this problem, the calculation of Mahalanobis distance, D^2 (approximately chi square distributed), based on the U statistic as described by Rao (1970) was added to the program. Since D^2 is additive, the change in D^2 (2 df) with each added variable did not contribute to the separation among groups. In addition to the incremental D^2 calculation, the program was modified to print out the classification matrix after each step.

To obtain empirical distributions of the D^2 statistic and classification speed, the following experiment was carried out. Ten separate sets of random data were generated, using a random number generator.⁴ Each set of data consisted of 70 random number (corresponding to flight variables) for each of 30 hypothetical "subjects." Ten "subjects" were arbitrarily assigned to each group (10 beginners, 10 intermediate, and 10 advanced). Each data bank, a 30 x 70 matrix of random numbers, was entered into the BMD07M stepwise discriminant program.

The results of the random data runs were quite surprising. Table 11 shows the number of "subjects" correctly classified by the stepwise discrimination procedure for each of the first 12 discriminating variables. It can be seen that on the average, the best one of the 70 random "flight variables" correctly classified 15.9 "subjects," and on the average only nine selected random "flight variables" are needed to classify correctly all 30 "subjects." The most typical discriminant of the ten runs (closest to average in separating ability) is shown in Figure 5.

These results indicate that the stepwise multivariate discriminant procedure is being misused in this application where it is expected to search large pools of variables (from approximately 50 up to 326) to select a few significant variables. Its use should be restricted to cases where the number of variables in the pool is much less than the number of pilots. The diversity of combinations available in such a large pool of random variables is put to quick use in separating groups.

Table 11. Number of "Random"
Pilots Correctly Classified

Number of Discriminating Variables	Worst of Ten Runs	Average of Ten Runs	Best of Ten Runs
1	14	15.9	18
2	17	18.8	21
3	19	21.0	24
4	19	23.0	26
5	22	24.9	28
6	22	25.0	29
7	23	26.7	30
8	25	27.4	30
9	27	28.5	30
10	28	29.2	30
11	29	29.9	30
12	29	29.9	30

⁴Ten uniformly distributed random numbers, each obtained by the CDC 6400 FTN random number generator (RGEN), were summed to obtain individual samples from an approximately normally distributed process having a mean of 5.0 and standard deviation of 0.8.

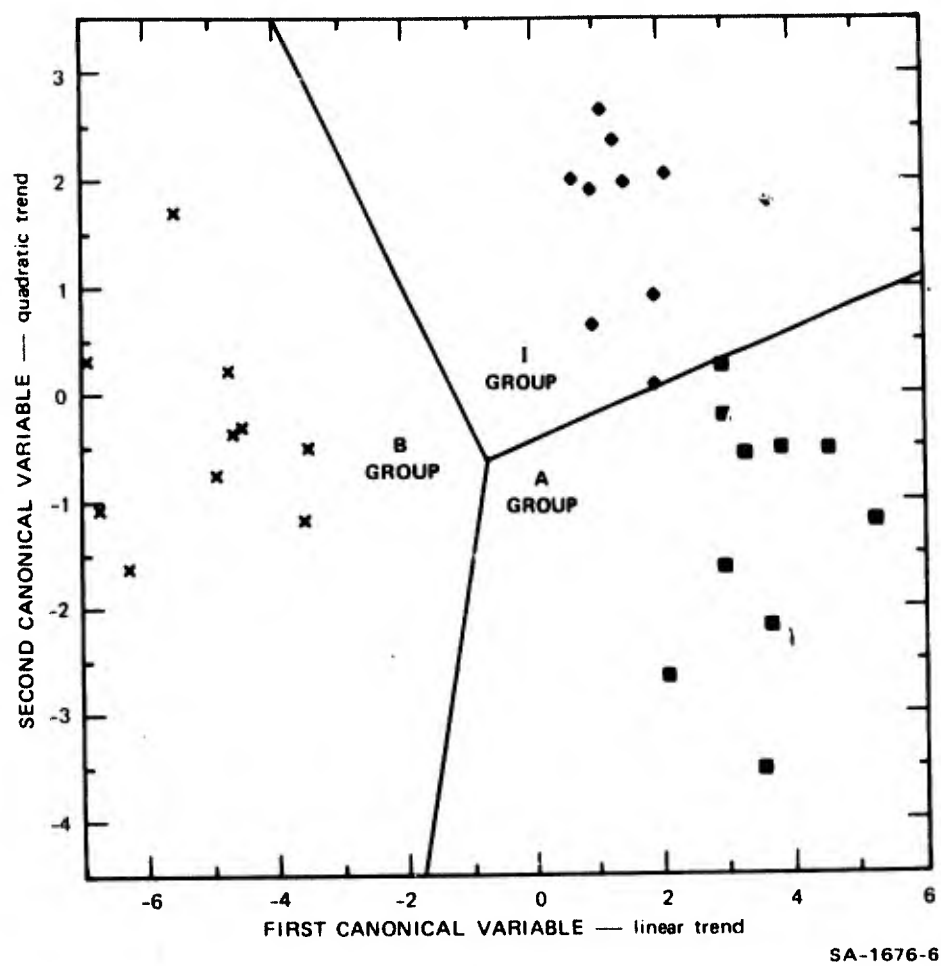


FIGURE 5 CLUSTER PLOT OF TYPICAL RANDOM DISCRIMINANT APPLIED TO 30 HYPOTHETICAL SUBJECTS

Experiment 1 Conclusions

The results with random data indicate that the multivariate discriminant analysis should not be used as a selection tool in this application. The fact that the majority of variables in the MM discriminant are not statistically significant in their own right suggests that the MM procedure is selecting variables that differentiate among the particular 30 Ss of the analysis, but will not be useful in differentiating among new Ss. This failure is useful because it suggests a rule for choosing candidate variables: a variable must be statistically significant in separating the three groups of Ss by itself. Only if this is true do we have some assurance that the variable shows a difference that will be repeated by other Ss.

This is exactly the approach used to obtain the AM discriminant. The large number of variables (70) entered in the multivariate analysis, however, still called for the analysis procedure to do the selection, possibly causing the resulting variables to be weighted so that particular, unrepeatable, differences among Ss are used to differentiate among the three groups. A better method of selection would be to increase the level of confidence (alpha) criterion for acceptance from the .10 level previously used to a higher level, say the .01 or the .001 level. A level of confidence of .01 in this study would have reduced the number of candidate variables from 70 to 18.

In addition to raising the significance level of acceptance of a variable, common sense indicates that many of the variables are highly correlated and hence redundant, and that some generic types of measurements are not effective above chance in generating statistically significant variables.

The describing functions of Figures 1 and 2 indicate that the tracking variables are highly correlated. Where differences among groups exist, they are repeatable across the entire frequency spectrum. Also, according to the way they are derived from these curves (Appendix A), gain and crossover measures are highly correlated, as are high frequency phase and equivalent time delay.

The results of Experiment 1 indicate that the correlation coefficients do not produce significant variables above the chance level. Only 7 out of 102 (6.8 percent) are significant at the 5 percent level. This is less than half as many as the other families and suggests that the correlations are not reliable in distinguishing among pilots.

With this background, the following rules for reducing the number of candidate variables are proposed:

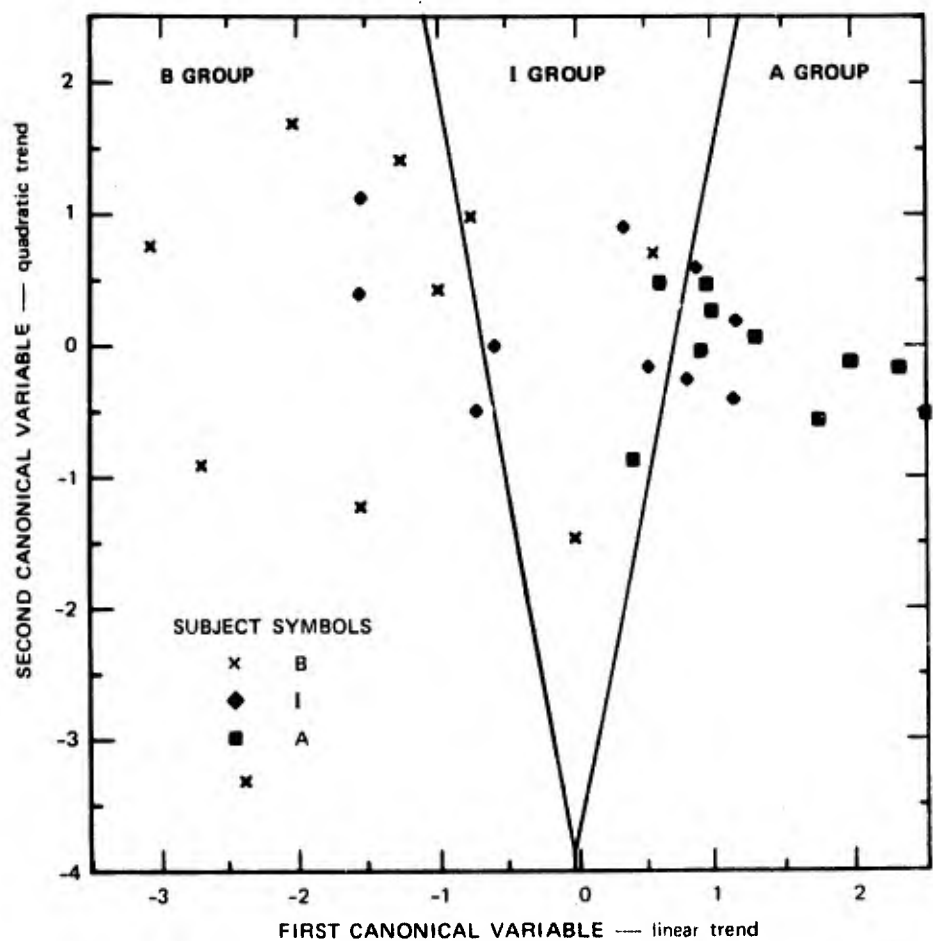
- **Rule 1** - Eliminate the tracking parameter (describing function) in favor of the parameters derived from them.
- **Rule 2** - From the derived tracking parameters eliminate the parameter of each following pair with the lowest F value.
 - Low frequency gain, low frequency crossover
 - High frequency gain, high frequency crossover
 - High frequency phase, equivalent time delay.
- **Rule 3** - Eliminate the 102 correlation coefficients.

In experiment 1, application of Rule 1 would eliminate 96 individual tracking gain and phase components (Variables 31 to 46, 50 to 65, 96 to 111, 115 to 130, 267 to 274, 297 to 304, 283 to 289, and 312 to 319). Application of Rule 2 would eliminate 3 variables from each of the 4 tracking analyses (12 variables) that are, by construction, highly correlated.

Applying these three rules to the data would reduce the number of variables from 326 to 116. Using significance level as the last criterion for selecting a small number of variables from the pool of 116, we find 5 qualifying variables above the 0.01 level and 14 above the 0.025 level. As a test of the efficacy of these rules, each of these groups was separately entered in the BMD07M program, and the two discriminants obtained were identical and are shown in Table 12 with their initial F values (2 and 27 df) and final F values (2 and 26 df). The individual values for the two canonical variables for each of the 30 Ss plotted using the coefficients and grand means of Table 12 and Eqs. (1) and (2) are shown in Figure 6.

Table 12. RAM Discriminant Summary

Variable Number	Name, Task	Initial F-Value	Final F-Value	1st Canonical Coefficient	2nd Canonical Coefficient	Grand Mean
241	Roll standard deviation, IV	7.27	4.69	-.39	-.45	4.05
294	High frequency roll crossover, II	11.30	8.12	17.70	-13.35	.166



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FIGURE 6 CLUSTER PLOT OF THE RAM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 1

One of the differences among the RAM discriminant and the previous discriminants is the dominance of the linear canonical variable in separating the three groups. With the AM, MM, and Random discriminants, cluster plots had a triangular shape; with the RAM discriminant, the clusters lie in a straight line. This difference further suggests that the three previous discriminants were building group differences from peculiar differences among *Ss* in the 30 *S* pool the same way that differences can be built up by using a pool of random numbers. It also seems logical and desirable that pilot performance measures should be measured on a single axis (the first canonical or linear variable) of increasing skill with monotonically increasing changes from B through I to A groups rather than the up-down-up changes resulting from the second canonical (quadratic) variable.

IV. EXPERIMENT 2

Introduction

Experiment 2 was a considerably expanded version of Experiment 1 designed to fulfill the following requirements:

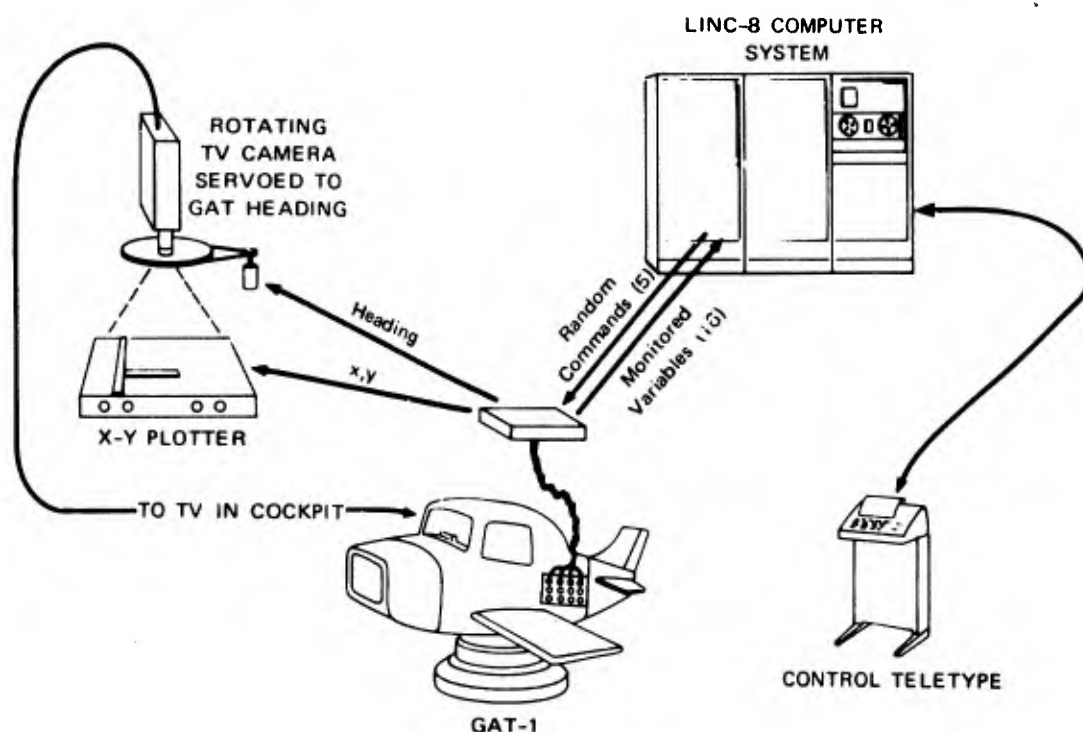
- Replicate the measurements of Experiment 1 to obtain data for verifying the reliability of the discriminants based on 30 new *Ss*.
- Include additional flight variables, particularly all the *Ss*' control inputs (throttle, rudder, elevator, and aileron).
- Determine if roll tracking alone was the task that discriminated among groups, or if it was the particular two-dimensional tracking procedure used in Experiment 1. For this purpose one-, two-, and three-dimensional tracking tasks (including roll) were explored, as well as tasks with varied bandwidth and amplitude of the roll command signal.
- Experiment with several types of direct and derived tracking measurements based on the remnant spectrum and cross-coupling between tracking tasks.

Method

Apparatus. In this experiment more flight variables were recorded and controlled, and a visual reference system was added as shown in Figure 7. The interface between the GAT-1 and LINC-8 computer was enlarged to allow continuous monitoring of eight additional flight variables (power, absolute heading, rate of turn, rudder, elevator, aileron, northing from a reference station, and radial distance from a reference station) and to allow the computer to introduce signals into three additional GAT-1 variables (yaw, altitude, and north-south position) for tracking tasks.

The LINC-8 computer program was modified to subtract a continuously changing ramp function from specified variables so that changes from the required profile could be monitored. For example, the actual altitude difference from the profile specified by 500 ft/min climb starting at an altitude of 500 ft could be monitored exactly like other, unchanging flight variables. The ability to monitor linearly changing variables was used to follow altitude deviations during steady climbs and descents and heading deviations during fixed rate turns.

The LINC-8 tracking program was expanded to permit tracking command signals to be composed of 16 different sine wave components. The Fourier analysis was expanded from 8 to 16 frequencies, and the ability to perform Fourier analysis of a flight variable at several different sets of frequencies was added. With 16 instead of 8 data points, the pilot-vehicle describing functions were expected to be smoother and the variables derived from them (like average gain, crossover frequencies, and equivalent time delay) were expected to be more stable. Analyzing one flight variable at the frequencies contained in the command signal of another flight variable is called a cross-frequency analysis. The cross-frequency analysis permitted the coupling from one variable to another during a multidimensional tracking task to be determined (i.e., in roll and pitch tracking how much of the pitch command the *S* coupled into roll and vice versa). Analyzing a tracking flight variable at frequencies not in any command signal permitted the self-generate response of the pilot, the remnant, to be measured. Breaking the remnant power into high and low frequency portions permitted estimates of the jerkiness or smoothness of the *S*'s control handling to be made.



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FIGURE 7 EQUIPMENT CONFIGURATION FOR EXPERIMENT 2

To carry out simple maneuvers entailing ground reference, the simulated ground reference system shown in Figure 8 was built. The visual reference system consisted of an x-y plotter and a closed circuit TV system. An 11 by 17 inch commercial x-y plotter was used to indicate the x and y coordinates of the GAT-1, using a scale of approximately 1 inch per mile. This afforded considerably greater resolution and smoothness than the original plotter supplied with the GAT-1.

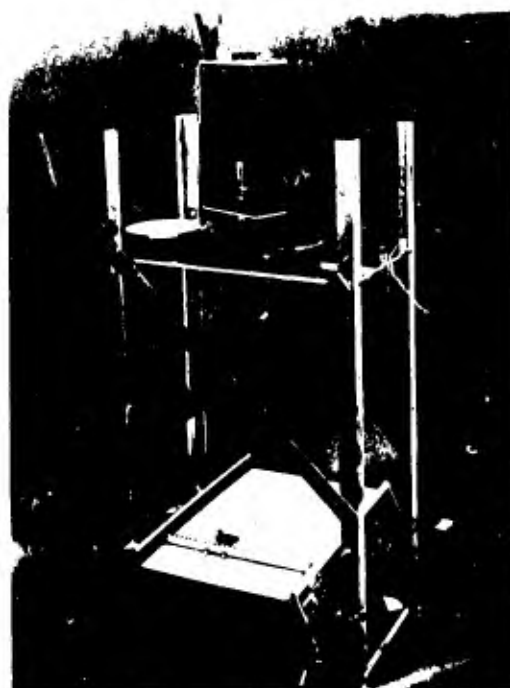
A TV camera, positioned about 3 ft above the x-y plotter on a stand, viewed about a 7 by 9 inch area on the plotter's bed. Served from a potentiometer in the base of the GAT-1, the TV camera followed rotation of the GAT-1. In this way, "up" on the TV monitor always corresponded to the direction of travel, and the turning direction to correct position errors was easily measured.

A small portable TV monitor on the instrument panel of the GAT-1 provided the test subject with ground reference information. On the monitor, the subject saw a plot of his required ground course and a small moving circle (bullseye) representing the position of the aircraft above the ground.

Subjects. Thirty Ss were selected on the basis of their flying experience, using the procedure described in Experiment 1. Many Ss in the advanced group volunteered for the test; the remainder were obtained by offering them \$10.00 for completing two test sessions, each approximately 2.5 hours long.



(a) HEADS-UP DISPLAY



(b) TV CAMERA ON ROTATING STAND

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TA 934583-10

FIGURE 8 GROUND POSITION VISUAL DISPLAY SYSTEM

The subject observes his changing position (bullseye) on the ground reference using closed-circuit TV. The ground track shown represents a circle 2 miles in diameter.

Procedure. After performing the same warm-up and the same four tasks of Experiment 1 (Tasks I through IV), each *S* was run through six additional tasks (Tasks V through X). Since 2,436 individual test measurements were made on each *S* in the test series, many having the same name but measured in different tests, a numbering system similar to that used for the variables of Experiment 1 was used here. The number of each measurement is given in Appendix C by numbers placed to the right of the computer printout. When more than one measurement is printed on a line, the variables are numbered consecutively from left to right across the line with only the number of the last variables on the line being given. The description of the computational procedure used to obtain the test variables is given in Appendix A.

Pilot Familiarization

All pilots followed the same warm-up procedure used in Experiment 1.

Simulated Flight Tasks

(1) Tasks I Through IV

Task I, Roll and Pitch Tracking; Task III, Roll and Pitch Tracking with Power Changes; Task III, Flight Profile; and Task IV, ILS Landing Approach, were the same as the corresponding tasks of Experiment 1 except for the enlarged set of measurements obtained.

(2) Task V—Roll Tracking

This task was the same as Task I in both its requirements of the *S* and its duration. Instead of the separate sum-of-sine command signals introduced into the roll and pitch axes, a command signal was introduced only into the roll axis. When combined with Task I and Task VI, this task provides data for comparison of one-, two-, and three-dimensional compensatory tracking tasks including roll tracking. The amplitudes of the individual roll command frequencies are given in Table 13. In addition to the means, standard deviations, and correlations among the 12 monitored variables, the roll describing function, roll remnant analysis, and test variables derived from them were obtained (Appendix C).

Table 13. Amplitudes of the Roll Command Frequencies (Task V)

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	28.72
13	0.025	19.90
16	0.031	16.16
20	0.039	12.93
25	0.049	10.34
33	0.064	7.82
41	0.080	6.30
51	0.100	5.04
63	0.123	4.10
81	0.158	3.19
101	0.197	2.56
127	0.248	1.98
161	0.314	1.60
203	0.396	1.27
255	0.498	1.01
321	0.627	0.81

(3) *Task VI—Roll, Pitch, and Yaw Tracking*

Task VI is the same as Task I in both its requirements of the *S* and its duration. Sum-of-sine command signals described in Tables 14, 15, and 16 were introduced into the three axes. It should be noted that this task was considered harder by many *Ss* than the other tracking tasks, and earned it the nickname "airsick." In addition to the analyses of Task V, cross-frequency and remnant analyses were performed on the tracking data. The test measurements obtained are indicated in Appendix C by name, and the computations required to obtain them are given in Appendix A.

Table 14. Amplitudes of the Roll Command Frequencies (Task VI)

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	14.18
13	0.025	10.21
16	0.031	8.29
20	0.039	6.63
25	0.049	5.29
33	0.064	4.01
41	0.080	3.23
51	0.100	2.58
63	0.123	2.10
81	0.158	1.63
101	0.197	1.31
127	0.248	1.04
161	0.314	0.82
203	0.396	0.65
255	0.498	0.52
321	0.627	0.41

Table 15. Amplitudes of the Pitch Command Frequencies (Task VI)

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
10	0.020	6.55
14	0.027	4.68
17	0.033	3.86
22	0.043	2.98
26	0.051	2.52
35	0.068	1.87
43	0.084	1.52
53	0.104	1.23
64	0.125	1.02
87	0.170	0.75
111	0.217	0.59
131	0.256	0.50
172	0.336	0.38
207	0.404	0.31
273	0.533	0.24
355	0.693	0.18

**Table 16. Amplitudes of the Yaw Command
Frequencies (Task VI)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
11	0.021	4.61
15	0.029	3.38
18	0.035	2.81
24	0.047	2.11
29	0.057	1.74
37	0.072	1.37
49	0.096	1.03
54	0.105	0.94
73	0.143	0.70
95	0.186	0.53
117	0.229	0.43
147	0.287	0.35
193	0.377	0.26
237	0.463	0.21
265	0.518	0.19
347	0.678	0.15

(4) Task VII—Reduced Bandwidth Roll Tracking

This task is identical to Task V in performance and analysis except that the reduced bandwidth command signal described in Table 17 was substituted for the one previously used. Frequencies above 0.1 Hz were reduced to 25 percent of the original amplitude. Frequencies of 0.1 Hz and lower were slightly increased in amplitude to keep the energy in the command signal (mean square) the same as that in the Task V command signal.

**Table 17. Reduced Bandwidth Roll-Tracking
Command Signal Amplitudes (Task VII)**

Number of Cycles in Run	Frequency (Hz)	Amplitude (degrees)
9	0.018	29.45
13	0.025	29.41
16	0.031	16.58
20	0.039	13.26
25	0.049	10.59
33	0.064	8.02
41	0.080	6.46
51	0.100	5.17
63	0.123	1.05
81	0.158	0.81
101	0.197	0.66
127	0.248	0.52
161	0.314	0.41
203	0.396	0.32
255	0.498	0.26
321	0.627	0.21

(5) *Task VIII--Reduced Amplitude Roll Tracking*

This task is identical to Task V in performance and analysis. The command signal was the same as that given in Table 13 except that the amplitudes were reduced by one-third to make the task easier.

(6) *Task IX--Ground Reference Turning Maneuver*

Task IX calls for the *S* to fly a circular path over the ground in full rough air while keeping his altitude constant at 1000 ft and his airspeed constant at 100 mph. The task was designed to be a half-standard turn (360 degrees rotation in four minutes) and *S* was so informed. *S* approaches from the west on the tangent line and performs one full turn. Because of the novelty of the task, *S*s were given one warm-up try before the monitored run. *S* called "Mark" when he met the circle, at which time *E* started the performance monitor. *S* was monitored for the first three minutes of the turning task. Unique flight variables recorded in this task were: the heading deviations from the heading profile specified by the half-standard turn (90° per minute) and the radius from the aircraft (bullseye) to center of the circle measured in feet.

(7) *Task X--Altitude and Position Tracking*

This task is similar to Task I in calling for the *S* to hold his altitude at 1000 ft and his airspeed at 100 mph. Instead of holding a constant heading as in Task I, however, *S* is requested to hold his north-south position constant using the visual reference system. The sum-of-sine command signals given in Tables 18 and 19 were added into position and altitude flight variables to make this a two-dimensional tracking task. The task corresponds to flying over a straight line on the ground at a constant altitude under severe side winds and up and down drafts. This task introduced two new compensatory tracking tasks: altitude and position tracking. Both of these tracking tasks require an additional degree of integration on *S*'s part more than the axis (roll, pitch, or yaw) tracking paradigms previously used. The tasks are, therefore, harder in that they require more anticipation and planning than axis tracking. Except for the new command signals, the analyses are the same as the two-dimensional analysis of Task I.

Table 18. Amplitudes of the North-South Position
Command Frequencies (Task X)

Number of Cycles in Run	Frequency (Hz)	Amplitude (Feet)
2	0.004	213
5	0.010	203
8	0.016	133
12	0.023	79
14	0.027	67
19	0.037	51
21	0.041	47
25	0.049	43

Table 19. Amplitudes of the Altitude
Command Frequencies (Task X)

Number of Cycles in Run	Frequency (Hz)	Amplitude (Feet)
1	0.004	27.7
4	0.010	26.1
7	0.016	14.6
10	0.023	10.4
15	0.027	6.9
18	0.037	5.4
23	0.041	3.8
32	0.049	1.5

Results

Each of the 2,436 test measurements was given a one-way analysis of variance to determine its relative importance in separating the three groups. The distribution of *F* values obtained from these analyses is shown in Table 20. The 420 variables that were statistically significant at the 5 percent level are listed in Appendix D, along with significance level, group, means, grand means, and standard deviation within a group. In addition to this tabular listing, the 420 significant variables have been marked in the final analysis printout in Appendix C by arrows so that they may be cross-referenced by name and easily tabulated.

Table 20. Distribution of F Values for Experiment 2

F Limits	Significance	Variables
0	0.50	1,024
1.0		372
1.5		219
2.0		198
2.5	0.10	137
3.0		66
3.35	0.05	142
4.24	0.025	122
5.49	0.01	61
6.49	0.005	40
7.81	0.002	24
8.81	0.001	31
Total		2,436

To determine which of the ten flight tasks contributed more statistically significant variables and to compare new tasks with the previous tasks, the breakdown by task of Table 21 was made. The most efficient tasks are Task I and Task V, both requiring roll tracking. The rest have lower, more or less equal percentages, except for Task X (altitude and position tracking with the visual reference system) which stands out with a lower percentage. Task IX, the other task using the visual reference system, has a payoff in significant variables similar to the coordinated turning portions of Task III not using the reference system. In general, the new tasks of Experiment 2 identified significant variables similar to those identified in Experiment 1.

Table 21. Breakdown of Important Variables of Experiment 2 by Task

Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Task I	240	66	28
Task II	240	40	17
Task III	424	54	13
Task IV	104	12	12
Task V	173	52	30
Task VI	579	89	15
Task VII	173	34	20
Task VIII	173	38	22
Task IX	90	13	14
Task X	240	22	9
Total	2,436	420	

The four generic types of measurements made in Experiment 2 are each broken down into two portions in Table 22 to assess the importance of the additional test variables introduced in Experiment 2. The upper number in Columns 2 and 3 is the number of Experiment 1 variables that were duplicated in Experiment 2. The second number is the number of additional test variables measured in Experiment 2. The third number is the total of the first and second numbers.

Table 22. Breakdown of Important Variables of Experiment 2 by Generic Type

Source of Variables	Number of Available Variables	Number Significant (5% Test)	Percentage Significant (5% Test)
Means			
Duplications	44	8	18
Additional	123	22	18
Total	167	30	18
Deviations			
Duplications	44	21	47
Additional	123	33	27
Total	167	54	32
Correlations			
Duplications	102	8	8
Additional	812	91	11
Total	914	99	11
Tracking			
Duplications	128	43	34
Additional	1,060	194	18
Total	1,188	237	20
Variable totals	2,436	420	

The number of statistically significant new means did not change proportionally, since 18 percent were significant in each case. The proportion of standard deviations and tracking measurements, however, decreased, and proportion of correlations increased. Overall, the proportion of statistically significant Experiment 1 variables was higher (25 percent) than the proportion of additional variables of Experiment 2 (16 percent).

Because of the large number of flight variables (16), an important question to ask is: Which direct measurements are essential? To answer this question as well as to compare new direct measurements of the flight variables (means and standard deviations) with the previous set, the data of Table 23 were obtained from Appendix C. The results in Table 23 are clear-cut because proportions and numbers of important direct measurements are generally either large or small.

This data suggests that the following flight variables be deleted from the experiment:

- Power
- Rudder
- Aileron
- Nothing
- Radius
- Glide Slope
- Left/Right turns
- Heading deviation

On the whole, the added flight variables were not so important as the ones previously used. Only two, turn rate and elevator, are regular contributors of significant variables. Of these, turn rate provides the highest number of significant variables.

Table 23. Breakdown of Important Means and Standard Deviations of Experiment 2

Flight Variable	Number of Test Measurements Available	Number Significant (5% Test)	Percentage Significant (5% Test)
Turn rate	28	13	46
Power	28	3	11
Rudder	28	1	4
Elevator	28	10	36
Aileron	28	1	4
Northing	20	0	0
Radius	2	1	50
Airspeed	28	9	32
Altitude	28	9	32
Fixed reference	20	7	
Changing reference	8	2	
Climb rate	28	6	21
Roll	28	10	36
Pitch	28	9	32
Yaw (heading)	28	11	39
Fixed reference	22	8	36
Changing reference ^a	6	3	50
Glide slope	2	0	0
Left/right turns	2	0	0
Total measurements	334	83	

^aReferred to as heading deviations in the computer analysis of Appendix C.

With the added ability to monitor a changing reference, as in the changing altitude and changing yaw (or heading) tasks, 14 new measurements were made in the flight profile. Five of these (35 percent) were statistically significant compared with 36 percent of the fixed reference altitude and yaw measurements. This is judged insufficient evidence to show that the changing reference monitoring capability contributed to pilot performance measurement.

The results of the roll, pitch, and yaw cross-frequency analyses are tabulated in Table 24. The denominators of each fraction-like entry represent the number of test variables available from the particular analysis [Fourier, mean square error (MSE), or derived] in combination with the particular flight variable - command frequency combination. The numerator of each fraction is the number of available test variables that are statistically significant (5 percent test).

There was little evidence from Table 24 suggesting that the remnant analyses were important. The proportion of variables accounting for mean square remnant error, the variables judged most important in this case, did not exceed 8 percent.

Considering the cross-frequency analyses of Table 24 (one flight variable analyzed at command frequencies of another axis), there was little to suggest that this cross-analysis is important. One possibly important combination was the pitch-at-roll combination with 6 of 18 variables statistically significant. In the three pitch-at-roll analyses carried out in Experiment 2, however, none of the six significant MSE variables were significant more than once each, suggesting that the pitch-at-roll differences among groups are not repeatable.

The roll, pitch, and yaw describing function analyses (roll-at-roll, pitch-at-pitch, and yaw-at-yaw reference in Table 24) were the most important tracking analyses, and the roll describing function was the most important of these. A survey of the seven variables derived from (or fitted to) each describing

**Table 24. Numbers of Significant/Available
Test Variables Pooled for All Roll, Pitch,
or Yaw Tracking Tasks**

Flight Variables at Given Frequencies	Fourier Analysis	MSE Analysis	Derived Variables
Roll at roll	90/240	15/36	21/42
Roll at pitch	8/64	3/18	1/8
Roll at yaw	8/32	0/6	0/2
Roll at remnant	10/80	3/36	
Pitch at roll	10/64	6/18	1/8
Pitch at pitch	15/96	4/18	6/21
Pitch at yaw	1/32	0/6	0/2
Pitch at remnant	3/32	0/18	
Yaw at roll	4/32	2/6	1/2
Yaw at pitch	4/32	0/6	0/2
Yaw at yaw	7/48	3/6	2/7
Yaw at remnant	0/10	0/6	

Table 25. Frequently Significant Tracking Measures

Derived Tracking Measurements	Number of Test Measures Available	Number Significant (5% Test)
High frequency roll gain	6	6
High frequency roll crossover	6	5
Low frequency roll gain	16	4
Low frequency roll crossover	16	4
High frequency pitch gain	13	2
High frequency pitch crossover	13	2

function showed that the most reliable significant variable was high frequency roll gain. In the six roll-tracking tasks, the high frequency roll gain measurement was statistically significant in separating the pilot groups in all six tasks. This and other frequently repeated significant measures are shown in Table 25.

These results suggest that the roll describing function is a very reliable measurement for measuring pilot performance. In six different tracking tasks of varying difficulty and dimensionality, the high frequency portion of the roll describing function was always statistically significant.

Table 26 breaks down the results of the altitude and position tracking tasks into three measurement families and six different cross-analyses. There was no evidence to suggest that any one of the 18 families of test measurements is useful in differentiating the groups of pilots. A probable explanation for this is that the difficulty of the task and the low tracking gains resulted in highly variable performances.

Table 27 shows a tabulation of the number of significant tracking variables in the single-axis analyses (roll and roll frequencies, pitch at pitch, and so on). The number of available variables included those of the frequency analysis, mean square error analysis, and derived variables (those fitted to the describing function). In comparing Tasks V, I, and VI, which are 1-, 2-, and 3-dimensional tracking, respectively, it was observed that Task V, 1-dimensional roll tracking, has the highest proportion of its variables statistically significant.

**Table 26. Numbers of Significant/Available
Test Variables for Position and Altitude
Tracking (Task X)**

Flight Variables at Given Frequencies	Fourier Analysis	MSE Analysis	Derived Variables
Position at position	1/24	0/6	0/7
Position at altitude	0/16	0/6	0/2
Position at remnant	0/8	0/6	
Altitude at position	3/16	0/6	0/2
Altitude at altitude	1/24	0/6	0/7
Altitude at remnant	1/8	0/6	
Totals	6/96	0/36	0/18

**Table 27. Comparison of Dimensionality
and Command Spectrum Based on All
Single-Axis Tracking Analyses**

Task	Tracking Axis	Number of Available Variables	Number Significant (5% Test)	Percent Significant (5% Test)
I	Roll	37	18	49
	Pitch	37	14	38
II	Roll	37	15	41
	Pitch	37	2	5
V	Roll	59	31	53
VI	Roll	59	22	37
	Pitch	59	9	15
	Yaw	59	12	20
VII	Roll	59	18	31
VIII	Roll	59	22	37

The results suggested that single coordinate roll tracking was best for separating the groups of pilots. The fact that single-axis roll tracking discriminated among groups contradicted the results of Krendel and McRuer (1960) who found that single-axis tracking did not discriminate among pilot skills. The explanation for this discrepancy probably lies in the different test environments. The "job sample" approach using the GAT-1 may have measured differences in skill levels, whereas the "bench-top" tests using joystick and display may not have provided a suitable test environment.

Using Table 27 to compare the three types of command signals used in the single-coordinate, roll-tracking tasks (Tasks V, VII, and VIII), it can be seen that the normal roll-tracking command signal (Task V) had the highest proportion of statistically significant test variables. The lower proportion (31 percent) of significant variables with reduced bandwidth roll tracking than with standard roll tracking (53 percent) suggested greater higher frequency amplitudes would be better in differentiating the three groups. The lower proportion of significant variables (37 percent) in reduced amplitude roll tracking than in standard roll tracking (53 percent) furnished further evidence in favor of this interpretation.

V. APPLICATION OF DISCRIMINANTS TO EXPERIMENT 2 DATA

Results

To determine how well the three discriminants obtained from the data of Experiment 1 separated the three groups of *Ss* in Experiment 2, the three discriminants (AM, MM, and RAM) were applied to Experiment 2 data. Measurements of the first and second canonical variables were obtained for each *S* using Eqs. (1) and (2) with the weights given in Tables 8, 10, and 12, and the measurements of test variables obtained from 30 new *Ss* for the three discriminants are shown in Figures 9, 10, and 11. The decision lines⁵ for separating the three groups are the same as shown earlier in the corresponding plots from Experiment 1. (Figures 3, 4, and 6.).

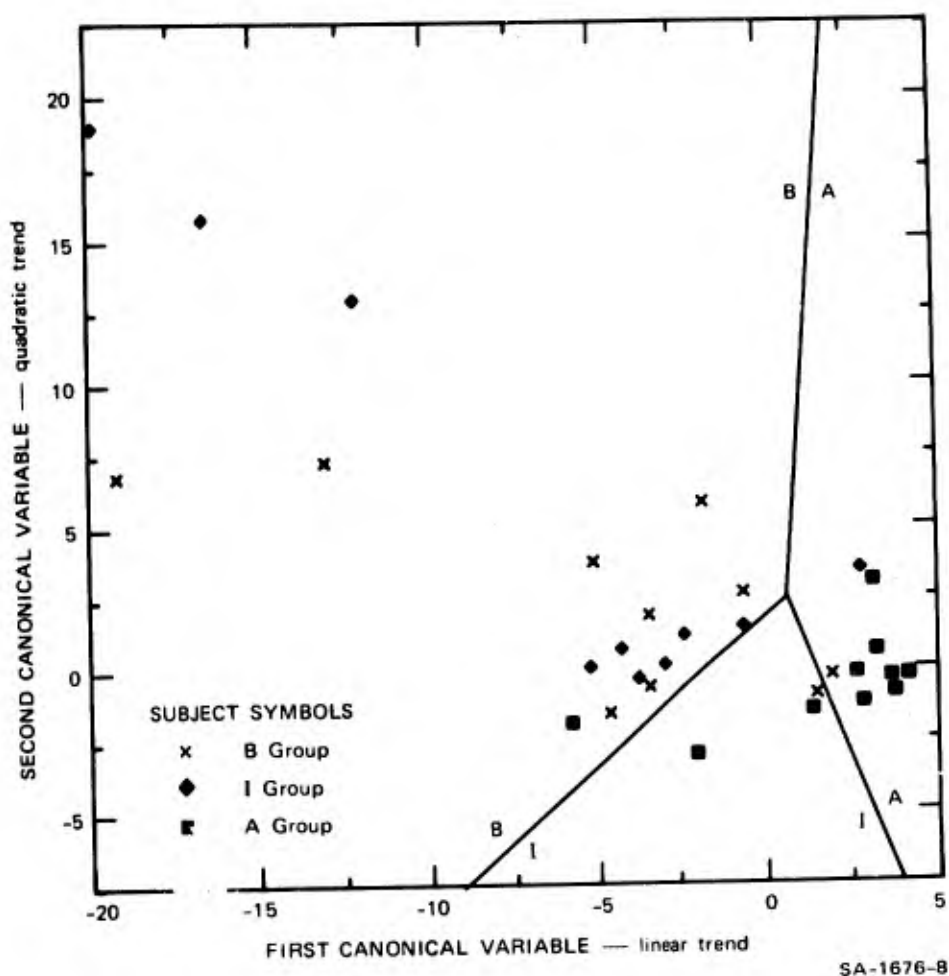
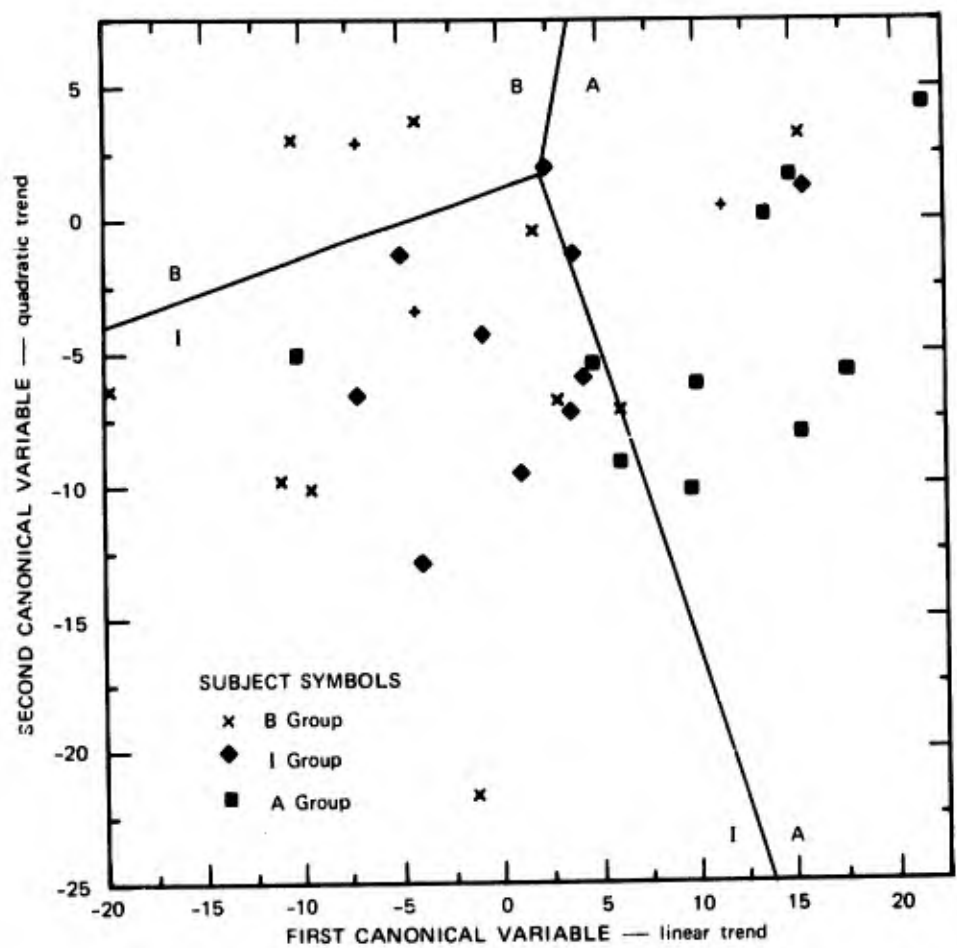


FIGURE 9 CLUSTER PLOT OF THE AM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

⁵ Sometimes called decision planes, a y-shaped group of three radial lines in this case.



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FIGURE 10 CLUSTER PLOT OF THE MM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

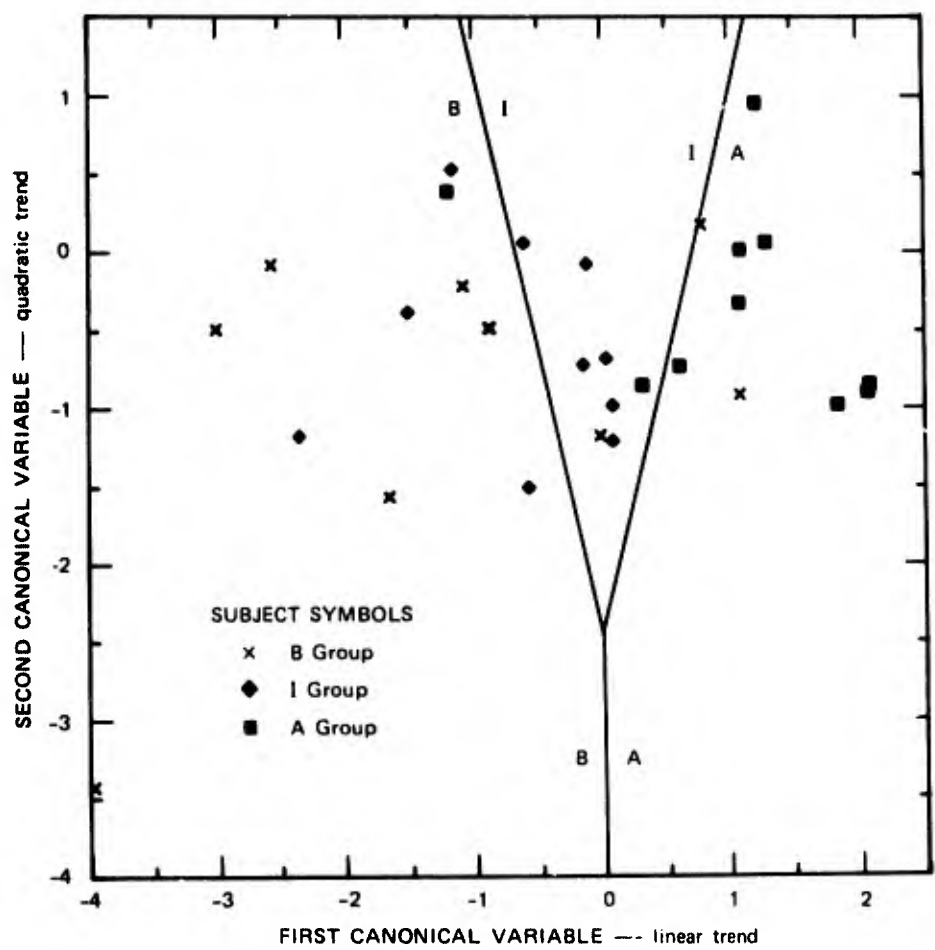


FIGURE 11 CLUSTER PLOT OF THE RAM DISCRIMINANT APPLIED TO THE 30 SUBJECTS OF EXPERIMENT 2

It is obvious from these plots that the three groups are more dispersed and overlap considerably more than when the discriminants were applied to the data from which they were derived (Figures 3, 4, and 6). The three new cluster plots suggest that the second canonical variable, accounting for the quadratic separation between the three groups, did not appear to influence the separation of the new pilots. The plots suggested that only the first canonical variable, accounting for the linear separation of the three groups, was meaningful. Such a linear separation could be made by constructing vertical decision lines for separating the three groups on Figures 9, 10, and 11.

To determine how well the three discriminants separate the Ss of Experiment 2, the classification matrices for each discriminant were obtained and are shown in Table 28. The number of Ss from Experiment 2 (B, I, and A identified on left of the matrices) that fell into each classification determined by the Ss from Experiment 1 (B, I, and A identified on top of the matrices) are shown.

Table 28. Classifications of Experiment 2 Subjects Using Discriminants Generated Using Experiment 1 Data

AM Classification		Experiment 1		
		B	I	A
Experiment 2	B	8	1	1
	I	9	0	1
	A	1	2	7
MM Classification		Experiment 1		
		B	I	A
Experiment 2	B	2	6	2
	I	0	7	3
	A	0	3	7
RAM Classification		Experiment 1		
		B	I	A
Experiment 2	B	6	1	3
	I	4	6	0
	A	1	1	8

The AM classification [chi-square (6) = 30.60, $p < .001$], the MM classification [chi-square (6) = 18.00, $p < .01$], and the RAM classification [chi-square (6) = 19.2, $p < .005$] are all significantly different from a random classification. Since all three are significantly different from a random classification, how well each discriminant identified the new Ss may be determined by inspecting the numbers of Ss identified correctly to group by the three discriminants as follows:

- AM classification - 15 (50%)
- MM classification - 16 (53%)
- RAM classification - 20 (67%)

which suggests that the RAM discriminant did the better job. Statistically, however, there is insufficient evidence [chi-square (2) = 1.90, $p < .05$] to show that the three discriminants were significantly different in their ability to classify Ss correctly.

Discussion

Although there is insufficient evidence to show statistically significant differences in the classifications of the AM, MM, and RAM discriminants, other evidence suggests that the AM and MM discriminants are equally poor in discriminating Ss' abilities and that the RAM discriminant is considerably better and typifies the best that can be done.

The evidence is based on the perfect discrimination of AM and MM on Experiment 1 data and the poor discrimination on Experiment 2 data, compared with the nearly identical RAM discrimination in both experiments. It is also based on the E's subjective observations of the Ss' abilities and rank orderings of Ss' scores in several test variables.

An interesting result of the multivariate analyses was that the AM and MM discriminants based on 8 and 15 variables actually classified fewer pilots correctly than the RAM discriminant, which is based on only 2 variables. This finding emphasizes the concern expressed previously that the stepwise multivariate discriminant analysis, when used as a tool to select among a large number of variables, will construct a discriminant from variables that optimize the separation of the three groups using unreproducible peculiarities of the test variables in the same way random variables are used.

Although the multivariate analysis procedure is set up to select variables and adjust their weights to separate the pilots into three groups, there is evidence that this is not possible nor desirable. In several instances, the experimenter observed that a pilot qualifying for the I group performed either like a B or an A group candidate. Some of the A group were subjectively judged to be performing as I group members. Consequently, the records of an I group subject who performed like a B group subject was examined more closely. His test score on one significant variable after another was compared to the three group means. It was found that his scores were typical of the average B candidate. Forcing the multivariate analysis to classify such an S into his proper experience group by selective weighting of the performance measures would result in a useless discriminant. Such a discriminant would force a S into an experience group in which he did not belong, and therefore would be based on something other than his skill, as indicated by flight hours.

Another indication of high degree of rank ordering in the data comes from the multivariate discriminant analysis of the RAM variables. After two of the set 14 variables entered into the analysis were selected, the *F*-to-enter for the remaining 12 dropped to low levels. Thus, all the remaining variables were highly correlated with the first two and did not improve the separation into groups. When the analysis program was forced to build a discriminant from all the variables by making the *F*-to-enter equal to zero, the program balked, dropped variables one after the other because they failed the tolerance test. The data, essentially a set of 14 equations in 30 unknowns, produced a singular solution because each of the 14 equations was nearly the same. A linear combination of these 14 most significant and highly correlated variables would be an excellent and stable measure of performance, but the multivariate analysis cannot construct such a combination.

This is probably the reason the RAM discriminant, composed on only two test variables, was the most successful. The ordering of the 30 Ss of Experiment 1 (shown previously in Figure 6) along the axis of the linear canonical variable is probably the correct ranking of the Ss' skill levels. This may be the best categorization that can be made. Whereas the other discriminants, including the discriminant based on

random numbers, classified all 30 of the Ss correctly, the RAM discriminant classified only 19 of them correctly.⁶ The similar ability of the RAM discriminant to classify Ss from Experiment 2 (20 correctly classified) further suggests that this is the best that can be done: the variable skill levels of Ss in each group limit the ability of performance measures to distinguish among groups.

Conclusions

This research effort assumed that the number of hours of flying experience a pilot has logged represents a defensible measure of his flying skill. The Federal Aviation Administration's qualification criteria for certification eligibility supports this assumption in its requirement for increased numbers of hours of flying experience for the higher levels of pilot ratings. Furthermore, the common notion of skill growth as a function of experience suggests that the assumption that pilot skill may be represented by hours of flying time is reasonable.

Forming groups of subjects based on different levels of flying experience in order to determine if their flying performance measurements could be used to categorize the subjects into their appropriate experience groups then was warranted based on the assumption of the relation of flying experience to flying skill. With this in mind, a flying performance measurement system was conceived in which combinations of aircraft parameters and derived variables based on them would indicate the skill level of the pilot who produced the measured performance. Presumably, the measured performance characteristics would permit designation of the hours of flying experience, that is, flying skill the performance represented. The pilot with 100 hours who flies like the average 150-hour pilot would be above average in skill and vice versa.

This study sought to evaluate by means of a cross validation test the results of earlier research, which demonstrated that measured aircraft parameters could be combined to classify accurately the flying performances of the pilots who produced them. The classification equations were generated by a multiple discriminant analysis in combination with other statistical and procedural techniques applied to the data of Experiment 1. Experiment 2 provided an additional set of nearly identical performance measures of different subjects.

If the discriminants derived from the subject's performance measurements of Experiment 1 could have been used to correctly classify the subject's performance measurements of Experiment 2, then the concept and the procedures employed would have been confirmed and further development of the statistical approach to the development of a pilot performance measurement system applying the concept and procedures would have been warranted. The results of the cross validation accomplished in Experiment 2, however, disconfirmed the concept and procedures tested and suggested that further refinement was not warranted.

The most important outcome of this research was not that discriminants derived from one set of performance measures were not perfectly accurate when used to classify new performance measures, but that the proliferation of performance measures decreased rather than increased the efficiency of the technique and that the variable skill levels of subjects in each group limited the ability of performance measures to distinguish among groups. This finding is interpreted as indicating that the idea of using combinations of measures selected from among a large number of aircraft attitude, or state variables to develop a measure of the skill of the pilot who controls the aircraft using the procedures employed in the present research, and the idea of relating pilot skill to hours of flying experience for purposes of establishing face validity of a measurement system are not viable and should not be pursued further.

Considering only these essentially negative conclusions based on the data, it would be easy to overlook the systematic strength of the research. The outcome of this study has been interpreted to indicate that the statistical approach cannot be applied in the development of a practical pilot performance measurement system. It is rarely the case where research results serve to demonstrate convincingly the inadequacy of the concept underlying the procedures, apparatus and materials used. The answer provided by this study is clear and the virtue of the work is defined by the clarity of the negative conclusion.

⁶ A RAM classification based only on the linear canonical variable would have raised this to 20 for Experiment 1 and would also have been 20 for experiment 2.

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APPENDIX A. COMPUTER PROCESSING OF THE GAT-1 DATA

Computation of Test Variables for Experiment 1

The LINC-8 computer accumulated 36-bit (triple-precision) sums of the input numbers

$$S_k = \sum_{i=1}^{64 \text{ RTIM}} \text{INPUT}_k(i)$$

and 36-bit sums of the input cross-products

$$P_{jk} = \sum_{i=1}^{64 \text{ RTIM}} \text{INPUT}_j(i) \text{INPUT}_k(i),$$

where k ($1 \leq k \leq 8$) and j ($1 \leq j \leq k$) were channel numbers, and 64 RTIM was the total number of 1/15-s steps taken in a given test run. The computer generated up to eight sums-of-sines command signals of the form

$$C_k(i) = \sum_{l=1}^8 A_{kl} \sin\left(\frac{2\pi F_{kl}}{64 \text{ RTIM}} i\right)$$

where A_{kl} was the amplitude coefficient for the k^{th} command signal (all equal in this case), F_{kl} was the frequency for the k^{th} command signal, and the sine function was approximated by a function table having 64 entries.

While a monitoring run was in progress, the computer saved all the input numbers, $\text{INPUT}_k(i)$, on a disk scratch file to obtain Fourier sums at the command signal frequencies after the test run had been completed. The Fourier sums for each channel, k , and at each command frequency, F_{kl} were:

$$A_{kl} = \sum_{i=1}^{64 \text{ RTIM}} \sin\left(\frac{2\pi F_{kl}}{64 \text{ RTIM}} i\right) \text{INPUT}_k(i)$$

$$B_{kl} = \sum_{i=1}^{64 \text{ RTIM}} \left(\frac{2\pi F_{kl}}{64 \text{ RTIM}} i\right) \text{INPUT}_k(i)$$

These data on punched tape served as the input for a second computer program that provided the usable output. This FORTRAN program first converted the numbers into the correct units by multiplying by the correct scale factor. The means and standard deviations were computed from the scaled sums, products, and Fourier coefficients as follows:

$$\text{MEAN}_k = S_k$$

$$\text{SD}_k = \sqrt{P_{kk} - S_k^2}$$

The between-signal correlation coefficients, r_{jk} , were

$$r_{jk} = \frac{\sqrt{P_{jk} - S_j S_k}}{SD_j SD_k}$$

To calculate an S gain and phase shift at each of the command signal frequencies, both the error signal and the response signal amplitude phase must be known. The error components, E_{kl} , are

$$|E_{kl}| = \sqrt{A_{kl}^2 + B_{kl}^2}$$

$$\angle E_{kl} = \tan^{-1} (A_{kl}/B_{kl})$$

To obtain these components for the S 's response, R_{kl} , the command signal, must be known. The command amplitudes were measured and built into the FORTRAN analysis program. By using the command amplitude, C_{kl} , the response was calculated by the complex number subtraction

$$R_{kl} = C_{kl} - E_{kl},$$

and the magnitude and phase of R_{kl} were computed in the same way that they were computed for E_{kl} . Finally, the gain and phase shift of the S at each command frequency were calculated and printed out:

$$GAIN_{kl} = \frac{|R_{kl}|}{|E_{kl}|}$$

$$PHASE_{kl} = \angle R_{kl} - \angle E_{kl}$$

The gain in decibels was determined by the formula

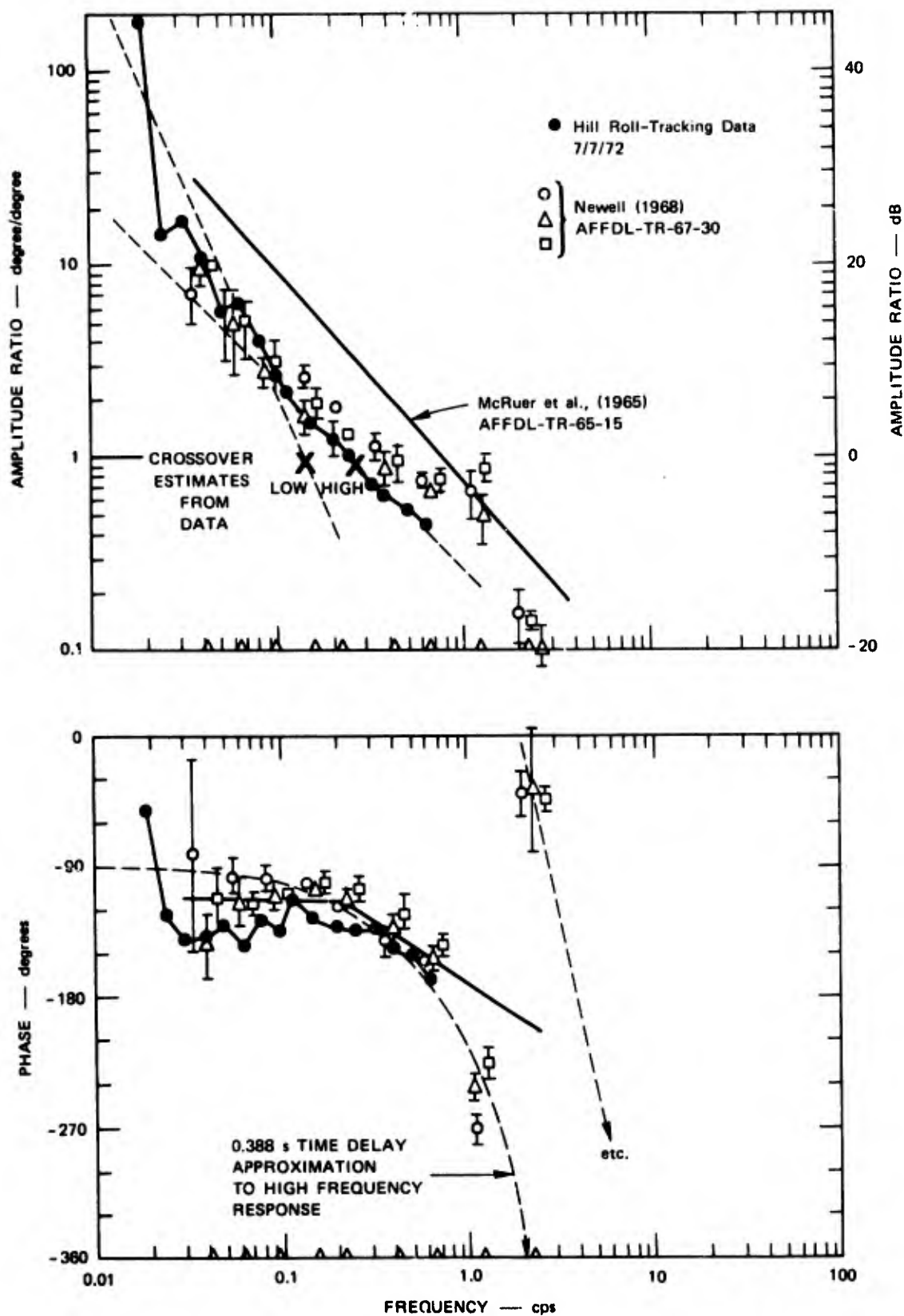
$$GAIN (dB)_{kl} = 20 \log_{10} GAIN_{kl}$$

The gain and phase shift plotted as a function of frequency became the "Pilot-Vehicle Describing Function" of McRuer et al., (1965). From this describing function, several derived measurements were obtained. The gains and phases from the higher and lower half of the frequencies⁷ were averaged together to produce the "Hi" and "Low" frequency gain and "Hi" and "Low" frequency phase listed in Appendix B. Figure A-1 illustrates how the other three derived parameters were obtained by least-mean-square fitting straight lines to the four higher and lower frequency gains and determining the intercept frequency at zero Hz. The equivalent time delay was obtained by a least-mean-square fit of the model, e^{-st} , to the higher frequency phase shifts to estimating the operator time delay parameter, t , of the McRuer et al., (1965) Simple Crossover Model.

Additional Test Variables for Experiment 2

The variables based on means, standard deviations, correlation coefficients, and the describing function of Experiment 2 were computed as described for Experiment 1. Additional analyses added in Experiment 2 were the cross-frequency and remnant analyses. Both of these required the Fourier analysis of a flight variable at different sets of frequencies instead of just one set. The procedure and formulation used have already been described in the first part of this appendix.

⁷The 4 highest and lowest frequencies when 8 are used, and the 8 highest and 8 lowest frequencies when 16 are used.



SOURCE: Graphs from F. D. Newell, *Human Transfer Characteristics in Flight and Ground Simulation for the Roll-Tracking Task*, AFFDL-TR-67-30, April 1968.

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FIGURE A-1 $Y_p Y_c$ WITH CONTROLLED ELEMENT K/s

In the cross-frequency analysis, the Fourier sine and cosine coefficients, A_{ke} and B_{ke} for the k^{th} flight variable were obtained and analyzed at the command frequencies of some other flight variable (the m^{th}). The isolation in decibels and the phase shift in degrees were calculated as follows:

$$\text{ISOLATION}_{ke} = 10 \log_{10} \left(\frac{A_{ke}^2 + B_{ke}^2}{C_{me}^2} \right)$$

$$\text{PHASE}_{ke} = \tan^{-1} (A_{ke}/B_{ke})$$

In the remnant analysis, the Fourier sine and cosine coefficients A_{ke} and B_{ke} for the k^{th} flight variable were analyzed at the remnant frequencies. These are a set of frequencies different from those of any other command signal. The amplitude of the remnant, relative to the total power in the k^{th} variable, was

$$\text{Amplitude}_{ke} = 10 \log_{10} \frac{(A_{ke}^2 + B_{ke}^2)}{SD_k^2}$$

In addition, the mean square error accounted for the k^{th} variable by the frequencies of the m^{th} variable was computed by summing 16 terms:

$$\text{MSE accounted for} = \sum_{e=1}^{16} A_{ke}^2 + B_{ke}^2$$

The high and low frequency portions were computed from the first 8 and second 8 of this sum.

Taken together, the MSE accounted for by the command signal input to the flight variable itself and the command signals input to other flight variables can be put in the form⁸ shown as follows:

MSE ACCOUNTED FOR BY

	Total MSE	Roll Frequency	Pitch Frequency	Yaw Frequency	Remnant Frequency
Roll Axis	164.82	18.19	9.99	80.70	8.02
Pitch Axis	7.67	.79	2.78	.46	.44
Yaw Axis	14.08	1.47	1.45	5.57	1.07

These data are the cross-coupling of the command inputs from one flight variable to another caused by the S . When cross-coupling MSE is substantially greater than the remnant MSE (a random set of frequencies), the excess can be attributed to S .

In addition to this basic cross-coupling matrix, the coefficients of a high frequency and low frequency cross-coupling matrices (based only on the upper and lower eight frequencies) were computed. Also, data for three normalized cross-coupling matrices (total, high frequency, and low frequency) were obtained from these three matrices by dividing each entry by the total MSE for its axis. In total, data for six different cross-coupling matrices were computed and printed for the two- and three-dimensional tracking analyses.

⁷ The 4 highest and 4 lowest frequencies when 8 are used, and the 8 highest and 8 lowest frequencies when 16 are used.

⁸ Numbers are taken from the roll, pitch, and yaw data of Appendix C. Units are degrees squared. The three-by-three array in the center is defined as the cross-coupling matrix.

**APPENDIX B. FINAL PRINTOUT OF 326 PARAMETERS
MEASURED ON ONE SUBJECT IN EXPERIMENT 1**

Variables significant at the 5-percent level are marked by arrows, \leftarrow , on the printouts that follow.

ZEIDLER, ADVANCED

ROLL AND PITCH TRACKING

VARIABLE NUMBERS

.....	MEAN.....	SD.....	UNITS
AIRSPED	105.76	2.89	MPH
ALTITUDE	978.53	25.31	FEET
CLIMB RATE	20.25	108.76	FT/MIN
ROLL	-.22	1.85	DEGREES
PITCH	3.60	2.03	DEGREES
YAW	.02	1.86	DEGREES

1	7
2	8
3	9
4	10
5	11
6	12

CORRELATION COEFFICIENTS, R(I,J)

-.398					
-.591	.232				
.262	-.085	-.140			
-.212	-.153	.249	.062		
.252	-.077	-.133	.995	.064	

13					
14	15				
16	17	18			
19	20	21	22		
23	24	25	26	27	

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ	GAIN	GAIN	PHASE
(HZ)		(DB)	(DEG)
.002	125.032	41.94	-275.34
.010	44.767	33.02	-183.66
.029	13.233	22.43	-154.67
.057	4.935	13.87	-139.44
.125	1.606	4.11	-129.29
.191	1.063	.53	-134.02
.307	.633	-3.97	-161.26
.467	.429	-7.35	-197.61

31	267	39
32	268	40
33	269	41
34	270	42
35	271	43
36	272	44
37	273	45
38	274	46

MEAN SQUARE FORCING FUNCTION	7291.19	DEG*DEG
MEAN SQUARE ERROR ACCOUNTED FOR	.41	DEG*DEG
MEAN SQUARE RESPONSE ACCOUNTED FOR	7258.42	DEG*DEG
LOW FREQUENCY GAIN	27.81	DB
LOW FREQUENCY CROSSOVER	.39	HZ
LOW FREQUENCY PHASE	-188.28	DEGREES
H1 FREQUENCY GAIN	-1.67	DB
H1 FREQUENCY CROSSOVER	.20	HZ
H1 FREQUENCY PHASE	-155.54	DEGREES
EQUIVALENT TIME DELAY	.65	SECONDS

29
275
276
277
278
279
280
281

PITCH ANALYZED AT THE PITCH FREQUENCIES

FREQ	GAIN	GAIN	PHASE
(HZ)		(DB)	(DEG)
.004	59.169	35.44	-268.45
.014	22.083	26.88	-240.83
.027	16.120	24.15	-202.28
.053	3.290	10.34	-160.50
.115	1.663	4.42	-150.45
.158	.996	-.04	-150.21
.283	.517	-5.73	-145.85
.535	.363	-8.79	-177.52

50	297	58
51	298	59
52	299	60
53	300	61
54	301	62
55	302	63
56	303	64
57	304	65

MEAN SQUARE FORCING FUNCTION	468.99	DEG*DEG
MEAN SQUARE ERROR ACCOUNTED FOR	.92	DEG*DEG
MEAN SQUARE RESPONSE ACCOUNTED FOR	480.05	DEG*DEG
LOW FREQUENCY GAIN	24.20	DB
LOW FREQUENCY CROSSOVER	.25	HZ
LOW FREQUENCY PHASE	-218.01	DEGREES
H1 FREQUENCY GAIN	-2.54	DB
H1 FREQUENCY CROSSOVER	.17	HZ
H1 FREQUENCY PHASE	-156.01	DEGREES
EQUIVALENT TIME DELAY	.54	SECONDS

49
47
48
305
306
307
308
309
310
311

ZETTLER, ADVANCED

VARIABLE NUMBERS

ROLL AND PITCH TRACKING WITH POWER CHANGES

	MEAN	SD	UNITS
AIRSPED	101.34	9.79	MPH
ALTITUDE	987.73	25.05	FEET
CLIMB RATE	16.50	118.45	FT/MIN
ROLL	-1.82	2.17	DEGREES
PITCH	4.18	2.19	DEGREES
YAW	-1.57	2.17	DEGREES

66	72
67	73
68	74
69	75
70	76
71	77

CORRELATION COEFFICIENTS, R(I,J)

-0.131				
-0.130	.248			
.100	-.218	-.172		
-.562	-.113	.300	.080	
.099	-.216	-.169	.997	.084

78				
79	80			
81	82	83		
84	85	86	87	
88	89	90	91	92

ROLL ANALYZED AT THE ROLL FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)
.002	292.448	49.32	-276.91
.010	12.490	21.93	-67.23
.029	10.035	20.03	-141.19
.057	7.984	18.04	-144.17
.125	1.511	3.59	-141.91
.191	.916	-.76	-144.19
.307	.639	-3.90	-156.56
.467	.471	-6.54	-185.28
MEAN SQUARE FORCING FUNCTION			7291.19 DEG*DEG
MEAN SQUARE ERROR ACCOUNTED FOR			.61 DEG*DEG
MEAN SQUARE RESPONSE ACCOUNTED FOR			7290.98 DEG*DEG
LOW FREQUENCY GAIN			27.33 DB
LOW FREQUENCY CROSSOVER			.26 HZ
LOW FREQUENCY PHASE			-157.38 DEGREES
HI FREQUENCY GAIN			-1.90 DB
HI FREQUENCY CROSSOVER			.19 HZ
HI FREQUENCY PHASE			-156.98 DEGREES
EQUIVALENT TIME DELAY			.62 SECONDS

96	282	104
97	283	105
98	284	106
99	285	107
100	286	108
101	287	109
102	288	110
103	289	111
95		
93		
94		
290		
291		
292		
293		
294		
295		
296		

PITCH ANALYZED AT THE PITCH FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)
.004	15.695	23.92	-22.28
.014	12.531	21.96	-178.85
.027	9.265	19.34	-110.60
.053	2.475	7.87	-125.06
.115	1.712	4.67	-124.82
.158	1.114	.94	-132.65
.283	.436	-7.21	-153.33
.535	.320	-9.90	-191.34
MEAN SQUARE FORCING FUNCTION			468.99 DEG*DEG
MEAN SQUARE ERROR ACCOUNTED FOR			1.54 DEG*DEG
MEAN SQUARE RESPONSE ACCOUNTED FOR			453.94 DEG*DEG
LOW FREQUENCY GAIN			18.27 DB
LOW FREQUENCY CROSSOVER			.45 HZ
LOW FREQUENCY PHASE			-109.20 DEGREES
HI FREQUENCY GAIN			-2.87 DB
HI FREQUENCY CROSSOVER			.17 HZ
HI FREQUENCY PHASE			-150.54 DEGREES
EQUIVALENT TIME DELAY			.57 SECONDS

115	312	123
116	313	124
117	314	125
118	315	126
119	316	127
120	317	128
121	318	129
122	319	130
114		
112		
113		
320		
321		
322		
323		
324		
325		
326		

ZEIDLER, ADVANCED

VARIABLE NUMBERS

1000-FOOT CLIMB

	MEAN	SD	UNITS
AIRSPED	95.09	6.11	MPH
CLIMB RATE	402.25	105.95	FT/MIN
ROLL	-1.35	2.12	DEGREES
PITCH	8.20	1.86	DEGREES
YAW	-1.08	2.14	DEGREES

131	136
132	137
133	138
134	139
135	140

CORRELATION COEFFICIENTS, R(I,J)

-0.555			
-0.707	.227		
-0.483	.515	.459	
-0.703	.226	1.001	.447

141			
142	143		
144	145	146	
147	148	149	150

ZEIDLER, ADVANCED

VARIABLE NUMBERS

LEVEL 360 TURN

	MEAN	SD	UNITS
AIRSPED	109.86	4.68	MPH
ALTITUDE	1444.79	41.37	FEET
CLIMB RATE	-15.00	160.02	FT/MIN
ROLL	6.93	26.73	DEGREES
PITCH	2.85	2.06	DEGREES

151	156
152	157
153	158
154	159
155	160

CORRELATION COEFFICIENTS, R(I,J)

-0.614			
-0.571	.174		
.456	-0.039	-.337	
-0.239	-.253	.639	-.280

161			
162	163		
164	165	166	
167	168	169	170

ZEIDLER, ADVANCED

VARIABLE NUMBERS

SLOW FLIGHT

	MEAN	SD	UNITS
AIRSPED	79.54	5.40	MPH
ALTITUDE	1433.59	38.43	FEET
CLIMB RATE	8.75	118.97	FT/MIN
ROLL	3.11	1.70	DEGREES
PITCH	7.33	1.54	DEGREES
YAW	3.40	1.73	DEGREES

171	177
172	178
173	179
174	180
175	181
176	182

CORRELATION COEFFICIENTS, R(I,J)

.185			
-.012	.174		
.386	-.041	.454	
-.248	-.117	.750	.258
.375	-.043	.450	.995
			.262

183			
184	185		
186	187	188	
189	190	191	192
193	194	195	196
			197

ZEIDLER, ADVANCED
DESCENDING 360 TURN

VARIABLE NUMBERS

	MEAN	SD	UNITS
AIRSPED	80.94	4.63	MPH
CLIMB RATE	-405.00	96.53	FT/MIN
ROLL	-16.3	20.02	DEGREES
PITCH	2.41	1.88	DEGREES

198	202
199	203
200	204
201	205

CORRELATION COEFFICIENTS, R(I,J)

-0.341	
-0.278	.147
-0.045	.580

206	
207	208
209	210 211

ZEIDLER, ADVANCED
500-FOOT DESCENT

VARIABLE NUMBERS

	MEAN	SD	UNITS
AIRSPED	74.79	3.88	MPH
CLIMB RATE	-195.50	68.28	FT/MIN
ROLL	-3.67	4.53	DEGREES
PITCH	.17	2.40	DEGREES
YAW	-3.48	4.55	DEGREES

212	217
213	218
214	219
215	220
216	221

CORRELATION COEFFICIENTS, R(I,J)

-0.681		
.611	-.435	
-0.773	.620	-.486
.610	-.440	.998

222		
223	224	
225	226	227
228	229	230 231

ZEIDLER, ADVANCED
ILS LANDING APPROACH

VARIABLE NUMBERS

	MEAN	SD	UNITS
AIRSPED	98.00	7.28	MPH
CLIMB RATE	-268.75	147.87	FT/MIN
ROLL	-11.02	3.74	DEGREES
PITCH	2.85	2.25	DEGREES
YAW	-10.88	3.76	DEGREES
GLIDESLOPE	-1.09	1.98	DEGREES
L/R	-.02	.47	DEGREES

232	239
233	240
234	241
235	242
236	243
237	244
238	245

CORRELATION COEFFICIENTS, R(I,J)

-0.707				
.192	-.133			
-0.656	.670	-.060		
.190	-.130	.991	-.057	
.063	.282	.109	-.174	.111
.258	.111	.203	-.134	.182

246				
247	248			
249	250	251		
252	253	254	255	
256	257	258	259	260
261	262	263	264	265 266

**APPENDIX C: FINAL PRINTOUT OF 2436 PARAMETERS MEASURED
ON ONE SUBJECT IN EXPERIMENT 2**

Variables significant at the 5-percent level are marked by arrows, ←, in the following computer printouts.

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ROLL ANALYZED AT THE REMNANT FREQUENCIES			
FREQ (HZ)	AMPLITUDE (DB)		
.006	-18.28		152
.016	-19.22		153
.021	-20.32		154
.045	-14.67		155
.104	-22.38		156
.139	-25.09		157
.240	-30.95		158
.389	-43.04		159
ROLL MEAN SQUARE ERROR (MSE)			22.72 DEG*DEG
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES			100.00 PCT
BY LOW FREQUENCIES ONLY			1.82 DEG*DEG
			8.00 PCT
BY HIGH FREQUENCIES ONLY			1.60 DEG*DEG
			7.02 PCT
			.22 DEG*DEG
			.97 PCT

PITCH ANALYZED AT THE ROLL FREQUENCIES			
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.002	-66.20	-108.77	167
.010	-42.65	-156.79	169
.029	-33.75	-204.75	171
.057	-26.72	-48.80	173
.125	-25.87	-111.13	175
.191	-20.90	-216.91	177
.307	-19.17	-212.40	179
.467	-24.65	-329.71	181
PITCH MEAN SQUARE ERROR (MSE)			3.23 DEG*DEG
MSE ACCOUNTED FOR BY ROLL FREQUENCIES			100.00 PCT
BY LOW FREQUENCIES ONLY			.07 DEG*DEG
			2.09 PCT
BY HIGH FREQUENCIES ONLY			.05 DEG*DEG
			1.61 PCT
LOW FREQUENCY PHASE			.02 DEG*DEG
			.49 PCT
HIGH FREQUENCY PHASE			-129.78 DEG
			-249.98 DEG

PITCH ANALYZED AT THE PITCH FREQUENCIES				
FREQ (HZ)	GAIN (DB)	GAIN (DB)	PHASE (DEG)	
.004	85.298	38.62	-249.04	192
.014	13.434	22.56	-248.94	195
.027	14.294	23.10	-187.14	198
.053	4.373	12.82	-176.72	201
.115	2.319	7.30	-151.62	204
.158	1.507	3.56	-141.28	207
.293	.834	-1.58	-138.27	210
.535	.415	-7.63	-145.48	213
MEAN SQUARE FORCING FUNCTION				501.87 DEG*DEG
PITCH MEAN SQUARE ERROR (MSE)				3.23 DEG*DEG
MSE ACCOUNTED FOR BY PITCH FREQUENCIES				100.00 PCT
BY LOW FREQUENCIES ONLY				1.36 DEG*DEG
				42.23 PCT
BY HIGH FREQUENCIES ONLY				.56 DEG*DEG
				17.30 PCT
LOW FREQUENCY GAIN				.81 DEG*DEG
				24.93 PCT
LOW FREQUENCY CROSSOVER				24.28 DB
				.23 HZ
LOW FREQUENCY PHASE				-215.46 DEGREES
HI FREQUENCY GAIN				.47 DB
HI FREQUENCY CROSSOVER				.24 HZ
HI FREQUENCY PHASE				-144.16 DEGREES
EQUIVALENT TIME DELAY				.402 SEC

PITCH ANALYZED AT THE REMNANT FREQUENCIES			
FREQ (HZ)	AMPLITUDE (DB)		
.006	20.92		227
.016	20.51		228
.021	20.45		229
.045	20.07		230
.104	18.06		231
.139	15.67		232
.240	-1.68		233
.389	9.52		234
PITCH MEAN SQUARE ERROR (MSE)			3.23 DEG*DEG
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES			100.00 PCT
BY LOW FREQUENCIES ONLY			1749.86 DEG*DEG
			54817.48 PCT
BY HIGH FREQUENCIES ONLY			1413.20 DEG*DEG
			43770.80 PCT
			356.66 DEG*DEG
			11046.68 PCT

ROLL ANALYZED AT THE REMNANT		FREQUENCIES	
FREQ	AMPLITUDE		
(HZ)	(DB)		
.006	-13.67		302
.016	-21.96		303
.021	-24.13		304
.045	-23.04		305
.104	-38.96		306
.139	-35.63		307
.240	-34.71		308
.389	-40.81		309
ROLL MEAN SQUARE ERROR (MSE)		34.96 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT		2.06 DEG*DEG	5.90 PCT
BY LOW FREQUENCIES ONLY		2.03 DEG*DEG	5.81 PCT
BY HIGH FREQUENCIES ONLY		.03 DEG*DEG	.08 PCT

PITCH ANALYZED AT THE ROLL		FREQUENCIES	
FREQ	ISOLATION	PHASE	
(HZ)	(DB)	(DEG)	
.002	-94.18	-1.38	407
.010	-42.70	-52.34	409
.029	-27.81	-281.67	411
.057	-23.93	-357.98	413
.125	-19.57	-30.98	415
.191	-32.45	-244.82	417
.307	-18.45	-247.87	419
.467	-17.82	-340.97	421
PITCH MEAN SQUARE ERROR (MSE)		5.66 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY ROLL		.174 DEG*DEG	2.99 PCT
BY LOW FREQUENCIES ONLY		.144 DEG*DEG	2.48 PCT
BY HIGH FREQUENCIES ONLY		.03 DEG*DEG	.49 PCT
LOW FREQUENCY PHASE		-173.34 DEG	428
HIGH FREQUENCY PHASE		-259.49 DEG	429

PITCH ANALYZED AT THE PITCH			FREQUENCIES	
FREQ	GAIN	GAIN	PHASE	
(HZ)		(DB)	(DEG)	
.004	15.300	23.69	-15.92	432
.014	16.493	24.35	-157.67	435
.027	7.268	17.23	-159.93	438
.053	3.618	11.15	-149.92	441
.115	2.504	7.97	-129.37	444
.158	1.324	2.44	-123.09	447
.263	.707	-3.01	-108.35	450
.535	.368	-8.69	-152.37	453
MEAN SQUARE FORCING FUNCTION			501.87 DEG*DEG	
PITCH MEAN SQUARE ERROR (MSE)			5.66 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY PITCH			2.92 DEG*DEG	51.61 PCT
BY LOW FREQUENCIES ONLY			2.44 DEG*DEG	43.05 PCT
BY HIGH FREQUENCIES ONLY			.48 DEG*DEG	8.56 PCT
LOW FREQUENCY GAIN			19.14 DB	460
LOW FREQUENCY CROSSOVER			.90 HZ	461
LOW FREQUENCY PHASE			-120.84 DEGREES	462
HI FREQUENCY GAIN			-.32 DB	463
HI FREQUENCY CROSSOVER			.22 HZ	464
HI FREQUENCY PHASE			-127.28 DEGREES	465
EQUIVALENT TIME DELAY			.328 SEC	466

PITCH ANALYZED AT THE REMNANT		FREQUENCIES	
FREQ	AMPLITUDE		
(HZ)	(DB)		
.006	-11.03		467
.016	-19.89		468
.021	-16.82		469
.045	-15.75		470
.104	-24.15		471
.139	-24.48		472
.240	-30.60		473
.389	-35.25		474
PITCH MEAN SQUARE ERROR (MSE)		5.66 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT		.82 DEG*DEG	14.51 PCT
BY LOW FREQUENCIES ONLY		.77 DEG*DEG	13.66 PCT
BY HIGH FREQUENCIES ONLY		.05 DEG*DEG	.86 PCT

1000 CLIMB

.....MEAN.....SD.....UNITS		
TURN RATE	-.43	.59 DEG/SEC
POWER	2457.28	37.52 RPM
RUDDER	1.03	4.66 PCT RIGHT
ELEVATOR	-2.51	1.39 PCT FRONT
AILERON	10.71	4.04 PCT RIGHT
NS DEV	-57.57	48.09 FEET
AIRSPED	93.14	3.15 MPH
ALTITUDE	1143.64	34.26 FEET
CLIMB RATE	627.16	181.53 FT/MIN
ROLL	1.04	2.97 DEGREES
PITCH	8.27	1.74 DEGREES
YAW	-1.11	2.16 DEGREES

[illegible]

LEVEL 360 DEGREE RIGHT TURN

	MEAN	SD	UNITS	
TURN RATE	2.88	.62	DEG/SEC	
POWER	2451.23	9.66	RPM	577
RUDDER	19.12	3.40	PCT RIGHT	574
ELEVATOR	-2.99	2.72	PCT FRONT	576
AILERON	-9.63	3.99	PCT RIGHT	578
HEAD DEV.	-320.95	7.77	DEGREES	580
AIRSPED	109.91	3.31	MPH	582
ALTITUDE	1567.37	54.27	FEET	584
CLIMB RATE	162.26	209.06	FT/MIN	586
ROLL	15.49	6.44	DEGREES	588
PITCH	2.66	1.97	DEGREES	590
				592

[illegible]

SLOW FLIGHT

	MEAN	SD	UNITS	
TURN RATE	-0.54	0.68	DEG/SEC	649
POWER	1746.61	179.22	RPM	651
RUDDER	4.08	6.86	PCT RIGHT	653
ELEVATOR	-2.24	2.69	PCT FRONT	655
AILERON	3.67	6.53	PCT RIGHT	657
NS DEV	-49.09	68.01	FEET	659
AIR SPEED	81.83	6.60	MPH	661
ALTITUDE	1502.81	33.66	FEET	663
CLIMB RATE	44.65	100.69	FT/MIN	665
ROLL	-2.42	2.99	DEGREES	667
PITCH	6.50	1.48	DEGREES	669
YAW	-1.40	2.19	DEGREES	671

[illegible]

DESCENDING 360 DEGREE LEFT TURN

	MEAN	SD	UNITS	
TURN RATE	-2.70	.39	DEG/SEC	
POWER	1291.10	115.26	RPM	739
RUDDER	-23.08	3.02	PCT RIGHT	741
ELEVATOR	-6.56	2.24	PCT FRONT	743
AILERON	21.07	5.82	PCT RIGHT	745
HEAD DEV.	30.76	21.37	DEGREES	747
AIR SPEED	75.20	3.70	MPH	749
ALTITUDE	1047.21	62.16	FEET	751
CLIMB RATE	-454.69	190.07	FT/MIN	753
ROLL	-7.11	2.66	DEGREES	755
PITCH	2.02	1.76	DEGREES	757

[illegible]

NUMBER OF
LAST VARIABLE
PRINTED ON LINECORRELATION COEFFICIENTS, $R(I, J)$ [illegible]

NUMBER OF
LAST VARIABLE
PRINTED ON LINE

CORRELATION COEFFICIENTS, $R(I, J)$ [illegible]

ROLL TRACKING

NUMBER OF
LAST VARIABLE
PRINTED ON LINE

.....MEAN.....SD.....UNITS		
TURN RATE	-0.53	1.23 DEG/SEC
POWER	2144.01	111.72 RPM
RUDDER	-2.93	13.39 PCT RIGHT
ELEVATOR	-1.92	3.09 PCT FRONT
AILERON	8.42	15.21 PCT RIGHT
NS DEV	-1062.37	156.26 FEET
AIR SPEED	98.00	1.75 MPH
ALTITUDE	1048.32	32.03 FEET
CLIMB RATE	02.99	144.73 FT/MIN
ROLL	1.16	7.94 DEGREES
PITCH	3.66	1.82 DEGREES
YAW	-2.16	3.014 DEGREES

CORRELATION COEFFICIENTS, $R(I, J)$ [illegible]

ROLL	ESTIMATED AT THE ROLL	FREQUENCIES
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FREQ (MHz)	GAIN (DB)	PHASE (DEG)	
.010	25.411	-109.46	1101
.025	21.862	-149.50	1104
.031	9.304	-99.09	1107
.039	12.031	-74.73	1110
.049	9.358	-162.91	1113
.064	4.399	-137.92	1116
.080	5.354	-161.17	1119
.100	4.256	-91.14	1122
.123	2.222	-133.00	1125
.150	1.550	-126.83	1128
.197	1.326	-124.43	1131
.248	.955	-134.42	1134
.314	.763	-141.02	1137
.396	.595	-155.98	1140
.498	.513	-173.88	1143
.627	.505	-192.49	1146

MEAN SQUARE FORCING FUNCTION	961.47 DEG*DEG		
ROLL MEAN SQUARE ERROR (MSE)	63.32 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL FREQUENCIES	29.88 DEG*DEG	47.18 PCT	
BY LOW FREQUENCIES ONLY	7.86 DEG*DEG	12.42 PCT	
BY HIGH FREQUENCIES ONLY	22.01 DEG*DEG	34.77 PCT	
LOW FREQUENCY GAIN	19.41 DEG		
LOW FREQUENCY Crossover	.36 HZ		
LOW FREQUENCY PHASE	-123.24 DEGREES		
HI FREQUENCY GAIN	-.72 DEG		
HI FREQUENCY Crossover	.26 HZ		
HI FREQUENCY PHASE	-147.76 DEGREES		
EQUIVALENT TIME DELAY	.474 SEC		

ROLL ANALYZED AT THE REMNANT FREQUENCIES

ROLL ANALYZED BY THE REMNANT FREQUENCIES			
FREQ	AMPLITUDE		
(HZ)	(DB)		
.023	-22.08		1160
.037	-31.07		1161
.041	-19.07		1162
.045	-18.60		1163
.059	-29.48		1164
.076	-21.69		1165
.094	-17.86		1166
.119	-21.78		1167
.146	-18.63		1168
.182	-25.01		1169
.242	-29.42		1170
.297	-34.49		1171
.385	-34.55		1172
.441	-33.25		1173
.607	-31.67		1174
.650	-41.74		1175
ROLL	MEAN SQUARE ERROR (MSE)	63.32 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES		5.23 DEG*DEG	8.26 PCT
BY LOW FREQUENCIES ONLY		4.06 DEG*DEG	6.41 PCT
BY HIGH FREQUENCIES ONLY		1.18 DEG*DEG	1.86 PCT

ROLL ANALYZED AT THE YAW			FREQUENCIES
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.021	-.12	-277.97	1374
.029	-.20	-260.31	1376
.035	2.01	-277.34	1378
.047	5.53	-291.96	1380
.057	9.43	-280.35	1382
.072	12.14	-317.48	1384
.096	13.52	-5.05	1386
.105	9.36	-12.07	1388
.143	7.77	-23.75	1390
.186	10.94	-33.71	1392
.229	10.25	-62.45	1394
.287	11.67	-78.75	1396
.377	11.88	-111.69	1398
.463	8.79	-136.02	1400
.518	7.41	-167.31	1402
.678	4.65	-214.82	1404
ROLL MEAN SQUARE ERROR (MSE)			164.82 DEG*DEG
MSE ACCOUNTED FOR BY YAW			100.00 PCT
BY LOW FREQUENCIES ONLY			80.78 DEG*DEG
BY HIGH FREQUENCIES ONLY			48.96 PCT
LOW FREQUENCY PHASE			74.76 DEG*DEG
HIGH FREQUENCY PHASE			45.36 PCT
			3.60 PCT
			1406
			1408
			1410
			1411
			1412

ROLL ANALYZED AT THE REMNANT			FREQUENCIES
FREQ (HZ)	AMPLITUDE (DB)		
.023	-25.98		1413
.037	-21.45		1414
.041	-23.18		1415
.045	-23.89		1416
.059	-21.07		1417
.076	-19.16		1418
.094	-24.38		1419
.119	-30.62		1420
.146	-23.51		1421
.182	-32.15		1422
.242	-35.25		1423
.297	-43.35		1424
.385	-39.39		1425
.441	-40.67		1426
.607	-48.58		1427
.650	-61.83		1428
ROLL MEAN SQUARE ERROR (MSE)			164.82 DEG*DEG
MSE ACCOUNTED FOR BY REMNANT			100.00 PCT
BY LOW FREQUENCIES ONLY			8.02 DEG*DEG
BY HIGH FREQUENCIES ONLY			4.87 PCT
			7.09 DEG*DEG
			4.30 PCT
			.93 DEG*DEG
			.56 PCT
			1430
			1432
			1434

PITCH ANALYZED AT THE ROLL			FREQUENCIES
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.018	-34.90	-188.63	1436
.025	-52.69	-202.83	1438
.031	-36.30	-15	1440
.039	-38.88	-337.45	1442
.049	-28.83	-109.49	1444
.064	-25.81	-56.46	1446
.080	-10.45	-54.76	1448
.100	-13.05	-311.54	1450
.123	-19.25	-235.88	1452
.158	-20.63	-60.46	1454
.197	-26.65	-41.36	1456
.248	-17.53	-202.29	1458
.314	-28.46	-223.72	1460
.396	-24.79	-274.57	1462
.498	-18.45	-339.58	1464
.627	-20.56	-77.41	1466
PITCH MEAN SQUARE ERROR (MSE)			7.67 DEG*DEG
MSE ACCOUNTED FOR BY ROLL			100.00 PCT
BY LOW FREQUENCIES ONLY			.79 DEG*DEG
BY HIGH FREQUENCIES ONLY			10.35 PCT
LOW FREQUENCY PHASE			.74 DEG*DEG
HIGH FREQUENCY PHASE			9.63 PCT
			.73 PCT
			1468
			1470
			1472
			1473
			1474

PITCH ANALYZED AT THE PITCH				FREQUENCIES
FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.020	24.721	27.86	-259.41	1477
.027	9.608	19.65	-243.41	1480
.033	7.989	18.05	-176.37	1483
.043	66.955	36.52	-24.40	1486
.051	5.611	14.98	-199.79	1488
.068	4.633	13.32	-148.75	1492
.084	2.484	7.80	-123.41	1495
.104	1.731	4.76	-136.44	1498

.125	1.623	4.21	-113.68			
.170	.888	-1.03	-120.90			1501
.217	.727	-2.77	-136.56			1504
.256	.678	-3.37	-128.64			1507
.336	.598	-4.47	-138.03			1510
.404	.385	-8.28	-118.23			1513
.533	.144	-16.86	-237.95			1516
.693	.271	-11.36	-199.72			1519
MEAN SQUARE FORCING FUNCTION				52.54 DEG*DEG		1522
PITCH MEAN SQUARE ERROR (MSE)				7.67 DEG*DEG		
MSE ACCOUNTED FOR BY PITCH				2.78 DEG*DEG	100.00 PCT	
BY LOW FREQUENCIES ONLY				1.37 DEG*DEG	36.22 PCT	1524
BY HIGH FREQUENCIES ONLY				1.41 DEG*DEG	17.86 PCT	1526
LOW FREQUENCY GAIN					18.37 PCT	1528
LOW FREQUENCY CROSSOVER				17.87 DB		1529
LOW FREQUENCY PHASE				.19 HZ		1530
HI FREQUENCY GAIN				-164.00 DEGREES		1531
HI FREQUENCY CROSSOVER				-5.49 DB		1532
HI FREQUENCY PHASE				.17 HZ		1533
EQUIVALENT TIME DELAY				-148.71 DEGREES		1534
				.482 SEC		1535
PITCH	ANALYZED AT THE YAW		FREQUENCIES			
FREQ	ISOLATION	PHASE				
(HZ)	(DB)	(DEG)				
.021	-24.88	-87.68				1537
.029	-26.52	-157.15				1539
.035	-23.35	-217.31				1541
.047	-16.70	-190.16				1543
.057	-16.62	-20.19				1545
.072	-8.66	-35.92				1547
.096	-15.56	-139.74				1549
.105	-7.93	-59.71				1551
.143	-8.41	-75.50				1553
.186	-6.30	-214.20				1555
.229	-10.18	-179.92				1557
.287	-7.14	-312.71				1559
.377	-6.22	-264.27				1561
.463	-12.93	-42.48				1563
.510	-10.92	-31.31				1565
.678	-17.23	-288.92				1567
PITCH MEAN SQUARE ERROR (MSE)				7.67 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY YAW				.46 DEG*DEG	6.01 PCT	1569
BY LOW FREQUENCIES ONLY				.36 DEG*DEG	4.71 PCT	1571
BY HIGH FREQUENCIES ONLY				.10 DEG*DEG	1.30 PCT	1573
LOW FREQUENCY PHASE						1574
HIGH FREQUENCY PHASE				-113.48 DEG		1575
				-190.35 DEG		
PITCH	ANALYZED AT THE REMNANT		FREQUENCIES			
FREQ	AMPLITUDE					
(HZ)	(DB)					
.023	-21.53					1576
.037	-21.67					1577
.041	-22.84					1578
.045	-29.68					1579
.059	-18.90					1580
.076	-26.57					1581
.094	-28.21					1582
.119	-18.36					1583
.146	-24.21					1584
.182	-35.36					1585
.242	-32.36					1586
.297	-34.51					1587
.385	-39.32					1588
.441	-40.17					1589
.607	-45.10					1590
.650	-38.01					1591
PITCH MEAN SQUARE ERROR (MSE)				7.67 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT				.44 DEG*DEG	5.67 PCT	1593
BY LOW FREQUENCIES ONLY				.39 DEG*DEG	5.13 PCT	1595
BY HIGH FREQUENCIES ONLY				.04 DEG*DEG	.54 PCT	1597
YAW	ANALYZED AT THE ROLL		FREQUENCIES			
FREQ	ISOLATION	PHASE				
(HZ)	(DB)	(DEG)				
.018	-37.35	-91.28				1599
.025	-20.34	-226.30				1601
.031	-24.16	-18.64				1603
.039	-25.98	-67.71				1605
.049	-20.12	-126.51				1607
.064	-12.77	-109.98				1609
.080	-16.75	-74.21				1611
.100	-23.32	-141.64				1613
.123	-31.59	-186.28				1615
.158	-19.46	-176.01				1617
.197	-22.86	-223.86				1619
.248	-20.97	-193.12				1621
.314	-22.64	-227.93				1623
.396	-20.44	-272.80				1625
.498	-27.67	-320.43				1627
.627	-29.38	-294.46				1629

YAW	MEAN SQUARE ERROR (MSE)	14.08 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY ROLL	FREQUENCIES	1.47 DEG*DEG	10.42 PCT	1631
BY LOW FREQUENCIES ONLY		1.44 DEG*DEG	10.20 PCT	1633
BY HIGH FREQUENCIES ONLY		.03 DEG*DEG	.22 PCT	1635
LOW FREQUENCY PHASE	-107.03 DEG			1636
HIGH FREQUENCY PHASE	-250.24 DEG			1637

YAW	ANALYZED AT THE PITCH	FREQUENCIES	
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)	
.020	-20.97	-181.98	1639
.027	-18.34	-306.84	1641
.033	-14.98	-32.11	1643
.043	-12.03	-122.50	1645
.051	-16.95	-77.05	1647
.068	-7.18	-296.51	1649
.084	-13.08	-217.61	1651
.104	-10.17	-299.42	1653
.125	-16.91	-341.31	1655
.170	-26.62	-354.27	1657
.217	-30.43	-28.53	1659
.256	-16.91	-12.04	1661
.336	-24.00	-31.10	1663
.404	-20.31	-61.79	1665
.533	-30.48	-9.55	1667
.693	-29.56	-359.44	1669

YAW	MEAN SQUARE ERROR (MSE)	14.08 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY PITCH	FREQUENCIES	1.45 DEG*DEG	10.33 PCT	1671
BY LOW FREQUENCIES ONLY		1.44 DEG*DEG	10.22 PCT	1673
BY HIGH FREQUENCIES ONLY		.02 DEG*DEG	.11 PCT	1675
LOW FREQUENCY PHASE	-191.75 DEG			1676
HIGH FREQUENCY PHASE	-173.72 DEG			1677

YAW	ANALYZED AT THE YAW	FREQUENCIES	
FREQ (HZ)	GAIN (DB)	PHASE (DEG)	
.021	10.751	20.63	1680
.029	7.377	17.36	1683
.035	5.190	14.30	1686
.047	2.547	8.12	1689
.057	3.641	11.22	1692
.072	1.328	2.46	1695
.096	.790	-2.05	1698
.105	.507	-5.90	1701
.143	.233	-12.66	1704
.186	.282	-11.00	1707
.229	.294	-10.63	1710
.287	.205	-13.77	1713
.377	.297	-10.56	1716
.463	.209	-13.61	1719
.518	.230	-12.78	1722
.678	.259	-11.41	1725

MEAN SQUARE FORCING FUNCTION	27.74 DEG*DEG		
YAW	MEAN SQUARE ERROR (MSE)	14.08 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY YAW	FREQUENCIES	5.57 DEG*DEG	39.60 PCT
BY LOW FREQUENCIES ONLY		4.59 DEG*DEG	32.62 PCT
BY HIGH FREQUENCIES ONLY		.98 DEG*DEG	6.98 PCT
LOW FREQUENCY GAIN	8.27 DB		1727
LOW FREQUENCY CROSSOVER	.08 HZ		1729
LOW FREQUENCY PHASE	-144.05 DEGREES		1731
HI FREQUENCY GAIN	-12.05 DB		1732
HI FREQUENCY CROSSOVER	.00 HZ		1733
HI FREQUENCY PHASE	-191.41 DEGREES		1734
EQUIVALENT TIME DELAY	.748 SEC		1735

YAW	ANALYZED AT THE REMNANT	FREQUENCIES	
FREQ (HZ)	AMPLITUDE (DB)		
.023	-17.71		1739
.037	-17.98		1740
.041	-33.12		1741
.045	-17.09		1742
.059	-21.37		1743
.076	-20.42		1744
.094	-23.61		1745
.119	-32.12		1746
.146	-29.42		1747
.182	-33.40		1748
.242	-41.74		1749
.297	-53.66		1750
.385	-64.74		1751
.441	-80.54		1752
.607	-60.00		1753
.850	-49.27		1754

YAW	MEAN SQUARE ERROR (MSE)	14.08 DEG*DEG	100.00 PCT	
MSE ACCOUNTED FOR BY REMNANT	FREQUENCIES	1.07 DEG*DEG	7.59 PCT	1756
BY LOW FREQUENCIES ONLY		1.04 DEG*DEG	7.42 PCT	1758
BY HIGH FREQUENCIES ONLY		.02 DEG*DEG	.17 PCT	1760

NUMBER OF
LAST VARIABLE
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CORRELATION COEFFICIENTS, $R(I, J)$ [illegible]

FREQ (M2)	GAIN	GAIN (DB)	PHASE (DEG)	
.010	13.010	22.29	-98.00	2026
.025	13.963	22.90	-154.21	2029
.031	9.441	19.50	-89.57	2030
.039	6.302	15.99	-78.66	2035
.049	4.542	13.15	-100.20	2036
.064	4.158	12.38	-129.75	2041
.080	10.861	20.72	-69.08	2044
.100	4.685	13.42	-100.93	2047
.123	1.496	3.50	-108.91	2050
.158	1.239	2.21	-75.64	2053
.197	1.790	5.06	-119.85	2056
.248	1.429	3.10	-132.21	2059
.314	.851	-1.40	-140.36	2062
.396	.591	-4.56	-161.31	2065
.498	.523	-5.63	-175.66	2068
.627	.584	-4.68	-194.85	2071
MEAN SQUARE FORCING FUNCTION				107.06 DEG*DEG
ROLL	MEAN SQUARE ERROR (MSE)		12.28 DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY ROLL				3.52 DEG*DEG
BY LOW FREQUENCIES ONLY				1.42 DEG*DEG
BY HIGH FREQUENCIES ONLY				2.10 DEG*DEG
LOW FREQUENCY GAIN				17.54 DB
LOW FREQUENCY Crossover				1.76 MZ
LOW FREQUENCY PHASE				-102.30 DEGREES
HI FREQUENCY GAIN				-3.30 DB
HI FREQUENCY Crossover				.27 MZ
HI FREQUENCY PHASE				-138.60 DEGREES
EQUIVALENT TIME DELAY				.452 SEC

FREQ	AMPLITUDE (HZ)	(DB)			
.023	-22.93				2045
.037	-24.42				2086
.041	-20.30				2087
.045	-22.65				2088
.059	-15.76				2089
.076	-17.64				2090
.094	-21.00				2091
.119	-40.25				2092
.146	-21.81				2093
.182	-21.55				2094
.242	-30.82				2095
.297	-25.14				2096
.385	-36.26				2097
.441	-46.86				2098
.607	-38.28				2099
.650	-40.55				2100
RULL MEAN SQUARE ERROR (MSE)			12.28	DEG*DEG	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES			1.14	DEG*DEG	9.25 PCT
BY LOW FREQUENCIES ONLY			.92	DEG*DEG	7.53 PCT
BY HIGH FREQUENCIES ONLY			.21	DEG*DEG	1.73 PCT

PINNEO, 10/24/72
GROUND REF. MANEUVER -- LEFT CIRCULAR TURN

NUMBER OF
LAST VARIABLE
PRINTED ON LINE

.....MEAN.....SD.....UNITS	
TURN RATE -2.10 2.13 DEG/SEC	2108
POWER 2057.44 101.34 RPM	2110
RUDDER -6.37 10.73 PCT RIGHT	2112
ELEVATOR -6.78 8.10 PCT FRONT	2114
AILERON 11.41 10.40 PCT RIGHT	2116
RADIUS 5924.10 419.19 FEET	2118
HEAD DEV. 9.66 19.48 DEGREES	2120
AIRSPEED 95.99 4.21 MPH	2122
ALTITUDE 1077.14 53.35 FEET	2124
CLIMB RATE 32.71 205.18 FT/MIN	2126
ROLL -8.96 11.61 DEGREES	2128
PITCH 4.17 2.74 DEGREES	2130

CORRELATION COEFFICIENTS, R(I,J)

.005		2131
-.631 .207		2133
.175 .443 .116		2136
.634 -.030 -.332 .147		2140
-.546 .394 .441 .197 -.399		2145
-.136 .590 .421 .137 -.216 .382		2151
-.050 -.573 -.070 -.176 -.062 -.231 -.426		2156
-.192 -.141 .188 -.071 -.252 -.205 .141 .368		2166
-.405 .255 .290 .198 -.313 .373 .256 .321 .435		2175
.928 .051 -.384 .075 .541 -.488 .057 -.084 -.105 -.377		2185
.205 -.141 -.159 -.506 .037 -.149 -.065 -.070 -.024 -.488 .316		2196

PINNEO, 10/24/72
GROUND REF. MANEUVER -- ALTITUDE AND POSITION TRACKING

NUMBER OF
LAST VARIABLE
PRINTED ON LINE

.....MEAN.....SD.....UNITS	
TURN RATE -.59 1.86 DEG/SEC	2198
POWER 2092.67 133.61 RPM	2200
RUDDER 3.26 13.52 PCT RIGHT	2202
ELEVATOR -3.75 2.49 PCT FRONT	2204
AILERON 4.01 11.38 PCT RIGHT	2206
NS DEV 76.21 233.38 FEET	2208
AIRSPEED 97.11 3.29 MPH	2210
ALTITUDE 1059.00 59.47 FEET	2212
CLIMB RATE 66.15 225.71 FT/MIN	2214
ROLL -2.36 8.90 DEGREES	2216
PITCH 4.34 2.12 DEGREES	2218
YAW -2.14 8.30 DEGREES	2220

CORRELATION COEFFICIENTS, R(I,J)

.106		2221
-.820 -.022		2223
-.251 .130 .217		2226
.720 .130 -.513 -.124		2230
-.409 .021 .351 .130 -.356		2235
-.160 -.010 .244 .052 -.133 .115		2241
.015 -.151 .011 -.023 -.026 -.177 .088		2248
-.013 .564 .078 .188 .030 .004 .461 .246		2256
.909 .083 -.534 -.236 .655 -.366 -.100 .048 -.012		2265
.105 -.441 -.134 -.127 .020 -.062 -.375 .208 -.607 .102		2275
.029 -.199 .02 -.173 .152 -.301 -.001 .204 .009 .101 -.074		2286

NS DEV ANALYZED AT THE NS DEV FREQUENCIES

FREQ (HZ)	GAIN	GAIN (DB)	PHASE (DEG)	
.004	2.971	9.46	-324.68	2289
.010	1.288	2.20	-87.99	2292
.016	.120	-18.38	-45.99	2295
.023	.487	-6.25	-163.38	2298
.027	.775	-2.22	-95.23	2301
.037	.507	-5.90	-149.88	2304
.041	.340	-9.38	-145.04	2307
.049	.233	-12.66	-183.99	2310
MEAN SQUARE FORCING FUNCTION				60451.86 FT*FT
NS DEV MEAN SQUARE ERROR (MSE)				54466.98 FT*FT
MSE ACCOUNTED FOR BY NS DEV FREQUENCIES				35055.93 FT*FT
BY LOW FREQUENCIES ONLY				27129.41 FT*FT
BY HIGH FREQUENCIES ONLY				7926.52 FT*FT
LOW FREQUENCY GAIN				-3.24 DB
LOW FREQUENCY CROSSOVER				.01 HZ
LOW FREQUENCY PHASE				-155.51 DEGREES
HI FREQUENCY GAIN				-7.54 DB
HI FREQUENCY CROSSOVER				.02 HZ
HI FREQUENCY PHASE				-143.54 DEGREES
EQUIVALENT TIME DELAY				4.133 SEC

NS DEV ANALYZED AT THE ALTITUDE FREQUENCIES				
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)		
.002	-1.76	-230.20		2325
.008	2.16	-247.03		2327
.014	6.13	-209.28		2329
.020	4.72	-212.68		2331
.029	3.03	-88.48		2333
.035	7.41	-35.70		2335
.045	5.16	-344.02		2337
.063	-4.44	-282.07		2339
NS DEV MEAN SQUARE ERROR (MSE)			54466.98 FT*FT	100.00 PCT
MSE ACCOUNTED FOR BY ALTITUDE FREQUENCIES			11159.90 FT*FT	20.49 PCT
BY LOW FREQUENCIES ONLY			10105.02 FT*FT	18.55 PCT
BY HIGH FREQUENCIES ONLY			1054.88 FT*FT	1.94 PCT
LOW FREQUENCY PHASE			-224.80 DEG	2346
HIGH FREQUENCY PHASE			-243.77 DEG	2347

NS DEV ANALYZED AT THE REMNANT FREQUENCIES				
FREQ (HZ)	AMPLITUDE (DB)			
.006	-11.94			2348
.012	-15.84			2349
.018	-22.24			2350
.021	-21.59			2351
.031	-32.17			2352
.039	-33.41			2353
.047	-24.78			2354
.053	-38.35			2355
NS DEV MEAN SQUARE ERROR (MSE)			54466.98 FT*FT	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES			5857.91 FT*FT	10.75 PCT
BY LOW FREQUENCIES ONLY			5610.66 FT*FT	10.30 PCT
BY HIGH FREQUENCIES ONLY			247.25 FT*FT	.45 PCT
				2357
				2359
				2361

ALTITUDE ANALYZED AT THE NS DEV FREQUENCIES				
FREQ (HZ)	ISOLATION (DB)	PHASE (DEG)		
.004	-15.08	-262.71		2363
.010	-10.13	-276.44		2365
.016	-10.71	-292.72		2367
.023	-17.52	-110.04		2369
.027	-9.06	-159.05		2371
.037	-13.28	-155.64		2373
.041	-20.13	-90.17		2375
.049	-20.69	-118.23		2377
ALTITUDE MEAN SQUARE ERROR (MSE)			3537.12 FT*FT	100.00 PCT
MSE ACCOUNTED FOR BY NS DEV FREQUENCIES			570.83 FT*FT	16.14 PCT
BY LOW FREQUENCIES ONLY			521.50 FT*FT	14.74 PCT
BY HIGH FREQUENCIES ONLY			49.33 FT*FT	1.39 PCT
LOW FREQUENCY PHASE			-235.48 DEG	2379
HIGH FREQUENCY PHASE			-189.64 DEG	2381
				2383
				2384
				2385

ALTITUDE ANALYZED AT THE ALTITUDE FREQUENCIES				
FREQ (HZ)	GAIN (DB)	GAIN (DB)	PHASE (DEG)	
.002	1.082	.69	-359.96	2388
.008	1.111	.91	-150.89	2391
.014	.762	-2.36	-150.50	2394
.020	.425	-7.44	-190.53	2397
.029	.337	-9.44	-117.70	2400
.035	.092	-20.72	-308.50	2403
.045	.864	-1.27	-147.37	2406
.063	1.944	5.78	-231.19	2409
MEAN SQUARE FORCING FUNCTION			940.55 FT*FT	
ALTITUDE MEAN SQUARE ERROR (MSE)			3537.12 FT*FT	100.00 PCT
MSE ACCOUNTED FOR BY ALTITUDE FREQUENCIES			1916.45 FT*FT	54.18 PCT
BY LOW FREQUENCIES ONLY			1844.97 FT*FT	52.18 PCT
BY HIGH FREQUENCIES ONLY			71.48 FT*FT	2.02 PCT
LOW FREQUENCY GAIN			-2.05 DB	2411
LOW FREQUENCY CROSSOVER			.00 HZ	2413
LOW FREQUENCY PHASE			-212.97 DEGREES	2415
HI FREQUENCY GAIN			-6.47 DB	2416
HI FREQUENCY CROSSOVER			.05 HZ	2417
HI FREQUENCY PHASE			-200.69 DEGREES	2418
EQUIVALENT TIME DELAY			6.868 SEC	2419
				2420
				2421
				2422

ALTITUDE ANALYZED AT THE REMNANT FREQUENCIES				
FREQ (HZ)	AMPLITUDE (DB)			
.006	-10.78			2423
.012	-14.85			2424
.018	-13.18			2425
.021	-23.27			2426
.031	-36.81			2427
.039	-30.85			2428
.047	-35.07			2429
.053	-31.00			2430
ALTITUDE MEAN SQUARE ERROR (MSE)			3537.12 FT*FT	100.00 PCT
MSE ACCOUNTED FOR BY REMNANT FREQUENCIES			645.46 FT*FT	17.12 PCT
BY LOW FREQUENCIES ONLY			597.90 FT*FT	16.90 PCT
BY HIGH FREQUENCIES ONLY			7.56 FT*FT	.21 PCT
				2432
				2434
				2436

**APPENDIX D. LIST OF THE STATISTICALLY SIGNIFICANT
VARIABLES FROM EXPERIMENT 2**

The tabular headings across the page are variable number, F value for testing the equality of three group means (with 2 and 27 df), significance level, mean value for each group of 10 Ss, mean value for all 30 Ss, and standard deviation within groups.

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
2	4.31	.025	.999640	.879360	.546870	.808623	.357310
14	4.82	.025	5.272	3.582	2.912	3.922	1.751
16	5.96	.010	80.631	45.988	34.038	52.886	31.788
18	4.24	.050	245.860	182.870	157.010	195.230	70.218
20	5.07	.025	7.801	6.398	4.074	6.074	2.637
21	4.29	.025	3.872	4.149	3.620	4.081	.905
22	4.22	.050	2.669	2.355	1.848	2.291	.638
24	7.96	.002	6.492	3.360	2.336	4.063	2.427
25	4.70	.025	.027028	-.085475	-.046652	-.035033	.083361
30	4.19	.050	-.004018	.646207	-.024307	.005961	.056061
33	5.32	.025	-.124395	-.062400	.164648	-.007382	.208562
34	4.96	.025	-.026789	-.094982	.029163	-.030869	.088243
44	4.76	.025	.105921	-.000634	.071792	.059026	.078904
48	6.20	.010	.094127	.173212	-.030853	.078849	.130724
50	4.16	.050	.035090	-.077361	.028370	.005366	.114704
51	4.66	.025	-.122680	.137515	-.071105	-.018757	.201738
55	4.80	.025	.110092	.004369	.010020	.041494	.085867
62	7.72	.005	.038522	-.075119	.011552	-.008349	.069869
72	4.52	.025	-.073360	.031502	.003460	-.012799	.080721
77	5.22	.025	.080250	.144680	.208360	.144130	.088683
81	3.53	.050	-.106258	-.059200	.066143	-.033105	.150003
90	3.67	.050	-.058383	.030284	.081661	.017852	.117003
99	4.31	.025	-.126.765	-.153.370	-.108.128	-.129.421	.34.644
100	3.94	.050	2.387	3.286	5.595	3.756	2.636
101	6.54	.005	5.812	9.820	13.614	9.749	4.823
103	6.50	.005	1.085	1.317	1.889	1.430	.513
104	6.65	.005	-.286	1.954	5.187	2.285	3.373
106	11.91	.001	.577230	.816420	1.173060	.855570	.274789
107	11.36	.001	-.5.611	-.2.178	1.122	-.2.222	3.159
109	10.42	.001	.388626	.482340	.693590	.521519	.153005
110	7.47	.005	-.9.263	-.6.716	-.3.330	-.6.437	3.444
112	11.78	.001	.328560	.421760	.522770	.424363	.089506
113	11.92	.001	-.9.922	-.7.675	-.5.766	-.7.788	1.905
115	3.73	.050	24.255	10.618	6.421	13.765	15.271
120	3.38	.050	15.818	20.121	27.931	21.290	10.565
121	6.11	.010	22.228	25.175	27.358	24.920	3.295
124	10.41	.001	-.6.270	-.3.654	-.6.697	-.3.540	2.732
125	9.38	.001	.109553	.149180	.224440	.161058	.060240
126	4.00	.050	-.161.840	-.157.900	-.148.330	-.156.023	10.988
127	3.52	.050	.674040	.642350	.554880	.623757	.104096
130	11.27	.001	-.19.105	-.24.603	-.29.746	-.24.485	5.012
131	4.84	.025	-.95.210	-.220.946	-.214.256	-.176.804	101.685
136	5.76	.010	-.7.568	-.4.489	-.11.532	-.6.529	7.370
148	4.17	.050	.338750	2.021515	.186526	.848930	1.577313
149	8.01	.002	.628	2.884	.972	1.495	1.359
150	4.76	.025	-.166.810	-.231.240	-.210.480	-.202.843	47.686
166	5.60	.010	-.50.648	-.59.785	-.62.826	-.57.753	8.469
169	4.09	.050	-.209.677	-.236.545	-.100.834	-.182.352	112.400
186	4.59	.025	.033068	.052529	.021408	.035668	.023203
187	3.46	.050	.564995	1.049960	.609350	.741435	.455635
192	8.21	.002	-.150.478	-.240.860	-.252.620	-.214.653	61.689
193	4.40	.025	18.941	32.352	19.858	23.717	11.298
194	3.56	.050	24.931	29.074	25.693	26.566	3.698
205	6.14	.010	.813	.920	1.291	1.008	.320
206	5.42	.025	-.2.722230	-.1.048210	1.949130	-.607103	3.215141
208	3.87	.050	.419871	.514850	.647030	.527184	.183637
209	3.41	.050	-.9.299	-.6.158	-.4.995	-.6.517	4.485
213	4.08	.050	-.181.610	-.171.530	-.153.020	-.168.720	22.699
214	3.38	.050	2.628	2.028	1.521	2.059	.953
218	4.44	.025	1.042880	1.116300	.745640	.968273	.294392
222	7.64	.005	-.152.744	-.189.270	-.190.600	-.177.538	24.577
223	4.08	.050	-.6.019	-.3.910	-.1.960	-.3.963	3.177
224	4.56	.025	.118442	.149846	.191026	.153105	.053884
226	3.75	.050	.481540	.455210	.354700	.430483	.109297
230	4.02	.050	-.23.545	-.27.834	-.13.617	-.21.665	11.498
234	4.66	.025	-.44.234	-.40.565	-.27.200	-.37.333	13.130
242	4.18	.050	1.002400	.823810	.568600	.798270	.33103
256	5.70	.010	99.469	60.822	43.330	67.807	38.071
257	4.94	.025	19.409	-.21.390	20.431	6.150	33.934
260	4.22	.050	7.222	5.580	4.205	5.669	2.325

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
261	5.95	.010	4.544	5.267	4.233	4.681	.687
264	5.16	.025	6.512	3.883	2.851	4.415	2.628
273	7.14	.005	-.139206	-.001906	.171951	.010280	.184490
288	3.50	.050	-.006764	.128328	-.045823	.025247	.154536
294	7.12	.005	.220089	.094655	.025134	.113293	.117071
303	4.35	.025	.127851	.112277	.296912	.179013	.155329
304	4.36	.025	-.047079	.042949	.010402	.002091	.069028
323	6.60	.005	-.105245	-.025951	.032134	-.033021	.084856
338	6.05	.010	14.564	21.408	22.767	19.580	5.653
341	3.68	.050	8.305	11.769	13.465	11.180	4.334
343	5.76	.010	1.134	1.334	1.769	1.412	.428
344	4.24	.025	-.095	2.321	4.667	2.298	3.657
346	5.98	.010	.665666	.785740	1.035000	.828815	.243611
347	4.13	.050	-.5.095	-2.274	.124	-2.415	4.065
348	3.56	.050	-150.290	-136.750	-137.320	-141.453	12.835
349	9.24	.001	.403260	.543190	.656640	.534363	.132016
350	9.24	.001	-.8.644	-5.387	-3.807	-5.946	2.566
352	8.36	.002	.335850	.396980	.486480	.406437	.082872
353	8.73	.002	-9.799	-8.081	-6.398	-8.093	1.820
360	3.68	.050	16.329	21.002	29.683	22.338	11.166
361	4.68	.025	21.984	27.237	26.935	25.385	4.311
362	3.61	.050	.246953	.330300	.632210	.403154	.337407
364	6.92	.005	-.5.908	-3.355	-1.354	-3.539	2.744
376	5.43	.025	-9.914	-3.186	-12.230	-8.444	6.376
389	4.96	.025	.712	2.631	.665	1.336	1.593
408	4.08	.050	-.33.536	-.33.939	-.38.300	-.35.258	4.134
412	4.33	.025	-20.058	-26.721	-29.588	-25.456	7.431
419	3.80	.050	-157.110	-256.039	-255.250	-222.800	92.297
422	4.04	.050	.987050	.486550	.322340	.598647	.544755
423	6.10	.010	8.885	6.394	5.333	6.871	2.334
424	4.02	.050	.957110	.447730	.294610	.566483	.547330
425	6.26	.010	8.490	5.816	4.856	6.387	2.379
429	6.47	.010	-206.080	-276.420	-250.960	-244.487	44.263
455	6.15	.010	40.497	44.083	53.126	45.902	8.297
457	6.09	.010	30.402	31.453	42.327	34.727	8.459
469	5.42	.025	-26.394	-19.266	-20.859	-22.173	5.082
487	4.68	.025	-1.943	-5.426	-2.597	-3.322	2.708
488	4.36	.025	4.936	6.526	3.280	4.914	2.458
500	3.53	.050	5.775	3.810	2.668	4.084	2.645
549	4.79	.025	-.058129	-.147780	.064203	-.047235	.153765
555	3.44	.050	.034145	.102043	-.294343	-.052718	.361342
577	4.44	.025	-2.475	-6.954	-3.424	-4.284	3.542
578	6.75	.005	4.750	8.251	4.374	5.792	2.603
590	3.40	.050	11.257	11.204	6.241	9.567	4.945
611	3.48	.050	.276876	.038365	.098624	.137955	.210092
627	4.98	.025	.769390	.480830	.656810	.635677	.205997
641	4.26	.025	-.453170	-.538190	-.262992	-.418117	.216009
648	6.34	.010	-.559290	-.459660	-.497030	-.505327	.063226
651	3.95	.050	379.200	304.662	234.450	306.104	115.169
654	3.79	.050	-4.840	-8.344	-5.284	-6.156	3.098
655	5.18	.025	5.017	7.421	4.448	5.629	2.193
660	3.50	.050	90.020	87.683	84.266	87.323	4.895
661	12.84	.001	12.187	7.488	6.325	8.667	2.739
663	4.66	.025	134.372	68.094	54.868	85.778	62.391
664	7.06	.005	-107.037	2.981	35.180	-22.959	88.740
667	4.71	.025	7.069	4.590	2.927	4.862	3.037
668	11.77	.001	5.586	7.273	7.578	6.812	.989
669	4.31	.025	3.750	2.764	2.165	2.893	1.220
691	8.82	.001	.385272	.095280	.076791	.185781	.184191
694	5.57	.010	.147135	-.261128	-.118506	-.070833	.292277
697	4.44	.025	-.215091	-.080901	.024759	-.090411	.180442
699	8.44	.002	-.537105	-.106922	-.099984	-.248004	.272511
704	4.63	.025	.237085	.010452	.140863	.129467	.167189
712	5.70	.010	.046517	.342819	.244127	.211154	.199859
720	4.17	.050	-.138924	-.436360	-.394110	-.323131	.249230
721	6.31	.010	-.378760	-.133594	-.199885	-.237413	.159618
723	5.80	.010	-.561000	-.192522	-.241592	-.331705	.262623
724	4.86	.025	.361146	.112138	.115460	.196248	.204823
731	4.52	.025	.400860	.204162	.183112	.262711	.178553
732	4.17	.050	-.128893	-.203062	.127874	-.068027	.268776

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
739	7.10	.005	1.856	1.709	.960	1.508	.571
743	3.51	.050	9.837	8.151	3.867	7.285	5.197
744	5.26	.025	-10.201	-14.198	-7.376	-10.592	4.728
745	4.44	.025	7.373	8.665	4.935	6.991	2.844
748	3.90	.050	406.928	167.948	380.516	318.464	209.696
752	4.19	.050	1120.	1101.	920.	1047.	170.
757	7.85	.002	10.857	9.252	4.834	8.314	3.521
759	5.54	.010	3.785	2.807	2.053	2.882	1.167
765	4.42	.025	.001944	.277550	.338515	.206003	.269657
789	3.53	.050	.430530	.245706	.095276	.257171	.282628
805	4.33	.025	.387703	.277475	.004000	.223059	.300180
806	4.46	.025	-.245475	-.178530	.059676	-.121443	.240242
816	5.72	.010	1.967	1.176	.935	1.359	.713
824	3.75	.050	13.652	8.001	8.080	9.911	5.291
827	3.44	.050	71.694	80.541	76.781	76.339	7.571
834	10.81	.001	9.459	5.939	3.103	6.167	3.063
842	4.11	.050	-.239479	.031376	-.024253	-.077452	.223195
844	3.48	.050	.085470	.367478	.215195	.222714	.239285
852	3.93	.050	.233433	-.056908	-.080769	.031919	.278865
856	4.46	.025	.111310	.263319	.477100	.290576	.290912
905	4.55	.025	-.537170	-.377544	-.502630	-.472448	.124506
906	5.20	.025	1.353	1.096	.578	1.009	.547
912	4.01	.050	3.070	2.162	1.811	2.348	1.026
915	4.78	.025	102.898	111.340	102.307	105.515	7.310
917	3.36	.050	907.290	673.160	904.180	828.210	231.803
922	8.63	.002	8.901	6.584	3.249	6.245	3.058
924	3.86	.050	3.279	2.341	1.692	2.437	1.285
926	4.25	.025	12.986	10.592	4.061	9.213	7.082
948	3.94	.050	.063499	.271872	.045534	.084636	.272641
959	5.38	.025	.855190	.802540	.563230	.740320	.212103
968	3.42	.050	.235903	.040453	-.044664	.077231	.245954
995	3.68	.050	-.224337	.006693	-.015597	-.077747	.210046
1009	4.89	.025	-.495440	-.451220	-.493570	-.480077	.035754
1010	3.74	.050	1.384	1.103	1.008	1.165	.320
1012	4.66	.025	95.115	50.070	33.937	59.707	46.451
1022	8.45	.002	6.121	4.139	2.454	4.238	1.997
1024	5.58	.010	80.978	44.507	29.991	51.825	35.173
1026	3.38	.050	230.120	170.990	125.201	175.437	90.493
1028	3.44	.050	10.825	8.858	7.635	9.106	2.744
1030	4.42	.025	2.784	2.255	1.662	2.233	.844
1032	5.05	.025	5.382	4.111	2.609	4.034	1.954
1041	8.10	.002	.111522	.344720	.474770	.310337	.204553
1051	4.03	.050	-.023515	.082402	.168354	.075747	.151304
1052	5.03	.025	.083696	.032532	-.008347	.035960	.065029
1075	4.50	.025	-.018653	.009285	.074157	.021596	.071006
1076	3.95	.050	-.035073	.000226	.062629	.009261	.078753
1082	3.66	.050	-.025985	.012461	.064545	.017007	.075092
1084	13.36	.001	-.459440	-.328490	-.176699	-.321543	.122402
1108	3.81	.050	5.989	8.023	10.702	8.238	3.827
1109	5.64	.010	14.466	17.357	20.091	17.305	3.744
1115	3.96	.050	7.863	10.847	13.053	10.588	4.140
1117	6.67	.005	2.423	2.701	4.233	3.119	1.193
1118	6.07	.010	6.637	8.003	12.154	8.931	3.688
1120	5.58	.010	1.612	2.337	3.028	2.326	.948
1121	7.12	.005	3.485	6.397	9.362	6.415	3.483
1123	3.42	.050	1.280	2.207	2.207	1.898	.915
1124	6.00	.010	1.621	5.587	6.710	4.639	3.452
1126	7.63	.005	1.027	1.262	1.793	1.361	.449
1127	7.33	.005	-.346	1.450	4.803	1.969	3.053
1129	5.87	.010	.743410	.979010	1.219210	.980543	.310472
1130	6.39	.010	-.3254410	-.755629	1.586260	-.807926	3.028134
1132	5.66	.010	.584790	.770000	.932980	.762590	.231578
1133	6.29	.010	-.5.147	-2.881	-.711	-2.913	2.797
1135	5.38	.025	.458720	.615400	.737680	.603933	.190654
1136	6.41	.010	-.7.494	-4.728	-2.778	-5.000	2.960
1138	4.98	.025	.371850	.479970	.587210	.479677	.158637
1139	6.00	.010	-.9.191	-6.939	-4.753	-6.961	2.864
1141	4.41	.025	.334530	.430030	.489020	.417860	.117381
1142	5.50	.010	-10.038	-7.718	-6.312	-8.022	2.537
1144	6.13	.010	.326420	.429390	.465570	.405793	.091438

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1145	7.65	.005	-9.947	-7.495	-6.724	-8.122	1.890
1147	4.39	.025	86.437	51.681	35.872	57.997	39.050
1149	4.30	.025	57.247	26.614	11.515	31.792	35.534
1150	5.32	.025	36.830	29.677	19.917	28.808	11.640
1152	3.84	.050	29.938	33.546	42.758	35.414	10.668
1153	3.39	.050	13.904	16.589	18.772	16.422	4.188
1154	5.46	.025	.123817	.176070	.225500	.175129	.068833
1156	6.89	.005	-5.475	-2.960	-1.022	-3.152	2.690
1157	5.99	.010	.146422	.200620	.250740	.199261	.067426
1170	3.78	.050	-37.401	-31.553	-30.961	-33.305	5.790
1173	4.64	.025	-45.703	-41.314	-38.255	-41.757	5.496
1174	7.41	.005	-54.996	-44.902	-45.917	-48.605	6.456
1175	3.96	.050	-52.551	-45.393	-45.074	-47.673	6.720
1181	3.98	.050	.375465	.507990	.882650	.588702	.416796
1182	5.67	.010	-.583550	-.476080	-.553240	-.537623	.073571
1195	6.38	.010	6.186	3.941	3.203	4.444	1.944
1197	5.29	.010	75.357	45.220	35.261	51.946	27.960
1203	3.99	.050	3.606	2.721	2.331	2.886	1.035
1205	4.52	.025	6.971	5.301	3.882	5.385	2.300
1209	7.38	.005	-.060928	-.151627	-.058979	-.090511	.061640
1215	3.85	.050	-.048887	-.116449	-.009492	-.058809	.087286
1231	5.26	.025	.056660	-.011996	-.042369	.000765	.069928
1245	5.98	.010	-.071550	-.145937	-.046104	-.087863	.067076
1247	3.40	.050	-.041173	-.111872	-.076707	-.076584	.060580
1261	5.01	.025	-.315350	-.378110	-.467740	-.384480	.109109
1262	3.65	.050	-.107872	.068057	.003126	-.012230	.147320
1266	3.87	.050	.026486	.090169	-.051090	.021855	.113771
1278	3.94	.050	5.290	13.216	15.001	11.169	8.273
1279	6.56	.005	13.921	19.914	22.267	18.701	5.376
1284	7.17	.005	4.409	4.164	9.600	6.058	3.626
1285	6.14	.010	11.558	11.509	18.266	13.778	4.959
1290	5.77	.010	1.907	2.899	3.828	2.878	1.265
1291	6.16	.010	4.221	8.558	10.998	7.925	4.373
1293	4.74	.025	1.675	2.031	4.395	2.700	2.147
1294	8.35	.002	3.406	5.722	11.154	6.761	4.351
1306	4.67	.025	-4.548	-1.179	-.387	-2.038	3.235
1311	11.30	.001	.314600	.438920	.572860	.442127	.121480
1312	11.19	.001	-10.844	-7.457	-4.949	-7.750	2.797
1314	8.34	.002	.334350	.401730	.516470	.417517	.100857
1315	8.03	.002	-9.887	-8.113	-5.923	-7.975	2.216
1317	5.71	.010	.310549	.375610	.463790	.383316	.101762
1318	3.91	.050	-11.112	-8.646	-6.946	-8.902	3.349
1320	3.96	.050	35.217	21.031	13.549	23.265	17.482
1322	4.36	.025	27.517	12.069	6.027	15.204	16.786
1325	3.53	.050	5.152	8.345	8.238	7.245	3.051
1326	8.35	.002	10.885	14.173	17.427	14.162	3.580
1327	4.25	.025	.150638	.185850	.392960	.243149	.200785
1329	6.79	.005	-5.735	-3.385	-1.494	-3.538	2.579
1330	4.87	.025	.149987	.186390	.236980	.191119	.062595
1334	7.82	.002	-172.240	-205.088	-109.855	-162.394	54.688
1335	5.75	.010	-11.621	-15.384	-21.275	-16.094	6.417
1344	3.62	.050	-142.151	-217.056	-118.060	-159.089	85.810
1364	3.78	.050	-110.723	-100.569	-199.990	-137.094	89.022
1384	7.23	.005	-151.173	-298.097	-327.490	-258.920	111.063
1392	7.31	.005	-17.801	-34.987	-32.343	-61.710	56.817
1395	3.54	.050	3.928	6.487	11.297	7.237	6.288
1396	5.82	.010	-116.519	-66.697	-80.012	-87.743	33.819
1397	7.33	.005	1.112	6.774	10.835	6.241	5.703
1399	5.80	.010	-.079	3.850	10.663	4.811	7.139
1401	3.40	.050	-.118	4.925	7.780	4.196	6.858
1403	5.31	.025	-3.440	3.071	6.612	2.081	6.997
1417	3.55	.050	-21.787	-24.784	-27.717	-24.763	4.977
1426	4.45	.025	-45.084	-41.747	-38.260	-41.697	5.117
1429	4.17	.050	12.174	5.871	3.843	7.296	6.725
1431	4.39	.025	11.420	5.281	3.060	6.587	6.533
1438	4.98	.025	-94.195	-151.009	-242.856	-162.687	106.260
1443	3.79	.050	-22.354	-25.529	-30.915	-26.266	7.033
1444	6.06	.010	-151.079	-205.823	-63.128	-140.010	92.512
1452	4.81	.025	-107.197	-104.792	-217.955	-143.315	93.209
1454	5.56	.010	-235.180	-141.220	-133.765	-170.055	75.833

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1485	4.12	.050	14.247	17.224	21.815	17.762	5.940
1508	4.20	.050	.648420	.751980	.926960	.775787	.217292
1509	3.77	.050	-4.395	-2.527	-1.051	-2.658	2.729
1511	4.60	.025	.391184	.533960	.634810	.519985	.180521
1512	4.05	.050	-9.481	-7.696	-4.527	-6.568	4.069
1514	7.74	.005	.302660	.420340	.548940	.423980	.140000
1515	7.84	.002	-11.534	-7.680	-5.602	-8.272	3.399
1532	3.73	.050	-6.175	-4.168	-2.633	-4.325	2.910
1533	3.48	.050	.162609	.189110	.232670	.194796	.059972
1539	4.44	.025	-183.140	-278.660	-249.570	-237.123	73.497
1602	3.77	.050	-18.785	-24.827	-26.176	-23.263	6.414
1606	10.71	.001	-18.438	-17.601	-26.685	-20.921	4.839
1612	3.47	.050	-16.479	-20.481	-22.932	-19.964	5.528
1621	3.53	.050	-234.200	-199.940	-183.644	-205.928	43.453
1630	3.93	.050	7.246	2.768	1.415	3.810	4.867
1632	3.89	.050	7.133	2.635	1.360	3.709	4.864
1637	4.08	.050	-267.360	-239.140	-241.290	-249.263	24.603
1640	6.84	.005	-15.468	-13.539	-24.772	-17.926	7.260
1648	3.92	.050	-11.985	-14.257	-20.280	-15.508	6.843
1658	4.03	.050	-21.905	-17.706	-25.378	-21.663	6.049
1667	4.54	.025	-201.090	-215.656	-115.370	-177.372	80.377
1693	3.47	.050	.712070	.780450	1.071450	.854657	.323923
1695	7.89	.002	-133.140	-98.146	-113.208	-114.831	19.762
1704	5.33	.025	-157.090	-104.787	-122.481	-128.119	36.444
1713	5.10	.025	-213.370	-167.930	-161.930	-181.077	39.398
1716	5.35	.025	-229.150	-167.502	-186.350	-194.334	43.180
1719	6.70	.005	-231.490	-180.801	-204.370	-205.554	30.997
1725	8.24	.002	-225.640	-188.220	-209.260	-207.707	20.659
1726	3.52	.050	17.819	11.894	8.743	12.819	7.767
1727	4.30	.025	40.407	42.978	56.696	46.694	13.353
1729	3.45	.050	36.480	39.343	50.340	42.054	12.456
1737	7.46	.005	-196.740	-160.430	-168.220	-175.130	22.126
1738	6.52	.005	.751890	.929100	.594170	.625053	.141898
1761	4.80	.025	-4485790	-4445910	-4487220	-4472973	.033828
1773	3.41	.050	100.164	103.350	101.069	101.528	2.813
1776	4.05	.050	54.040	41.997	33.525	43.187	16.200
1780	4.13	.050	8.333	6.293	4.955	6.527	2.646
1784	4.22	.050	4.474	3.224	2.257	3.318	1.711
1793	4.01	.050	.134787	.340841	.418120	.297916	.231215
1806	3.94	.050	-.009359	.037663	.032833	.020379	.041207
1821	3.41	.050	.805470	.584100	.574022	.654531	.223996
1830	4.19	.050	.080772	.121436	.005674	.069294	.090683
1832	6.35	.010	-.052592	.050763	.066964	.021712	.081389
1837	3.96	.050	.059112	.085934	.178344	.107797	.099427
1839	7.10	.005	.084075	.193720	.082844	.120213	.075574
1840	4.79	.025	-.009659	.023658	-.002382	.003939	.025477
1842	4.15	.050	.314995	.125781	.159677	.200151	.156658
1850	3.90	.050	-.043085	.036987	.097268	.030390	.112744
1867	3.53	.050	10.520	12.510	15.141	12.724	3.901
1870	4.58	.025	7.611	10.873	12.652	10.579	3.779
1876	4.35	.025	1.746	5.661	7.500	4.969	4.457
1882	5.74	.010	-2.245277	2.044780	2.758155	.852552	3.573461
1884	3.74	.050	.618700	.843830	.973540	.812023	.293610
1885	4.37	.025	-4.847	-2.391	-.385	-2.541	3.382
1890	5.97	.010	.390970	.561460	.600590	.517673	.144273
1891	7.43	.005	-8.885	-5.192	-4.634	-6.237	2.679
1892	4.46	.025	-185.650	-156.310	-164.260	-168.740	22.711
1893	6.56	.005	.357120	.465820	.529600	.450847	.107711
1894	5.90	.010	-9.882	-6.746	-5.594	-7.407	2.889
1896	10.46	.001	.355250	.457570	.559650	.457490	.099950
1897	11.88	.001	-9.267	-6.894	-5.713	-7.125	1.869
1899	5.24	.025	50.251	21.472	12.556	28.093	27.216
1901	5.05	.025	47.459	19.382	10.634	25.825	27.080
1906	3.61	.050	.158429	.213960	.269820	.214070	.092676
1908	7.28	.005	-4.926	-2.060	-.468	-2.485	2.649
1909	5.48	.025	.149069	.207822	.267310	.208067	.079892
1921	3.37	.050	-34.600	-29.471	-28.514	-30.862	5.641
1934	4.53	.025	-.484460	-.450670	-.487630	-.474253	.030420
1947	3.85	.050	4.240	3.890	2.322	3.484	1.647
1950	3.55	.050	36.719	-4.175	41.794	24.613	42.010

STATISTICALLY-SIGNIFICANT VARIABLES FROM EXPERIMENT 2

VARIABLE	F	SIGNIFICANCE	B MEAN	I MEAN	A MEAN	MEAN	STD.DEV.
1956	4.12	.050	-1.651210	1.135849	-1.182480	-.565947	2.324387
1957	4.48	.025	3.667	3.101	1.799	2.856	1.430
1966	4.37	.025	-.145823	.056273	.162555	.024335	.236917
1975	4.38	.025	-.025901	.164266	.071756	.070040	.143737
1977	5.55	.010	.150489	.041910	.047450	.079950	.082083
1983	4.43	.025	.104619	-.009727	.037626	.044173	.086295
2001	4.07	.050	.019401	.088354	.037110	.048288	.056099
2006	3.69	.050	.024324	.006092	-.068177	-.012587	.080618
2009	5.69	.010	-.415650	-.350663	-.213401	-.326571	.136939
2010	4.39	.025	.027915	.135646	.146416	.103326	.098937
2026	3.58	.050	-168.378	-166.003	-88.787	-141.056	75.661
2037	4.60	.025	-170.550	-102.627	-127.273	-133.483	50.689
2040	4.80	.025	7.384	11.922	12.133	10.347	3.730
2043	4.24	.050	4.644	6.078	10.536	7.086	4.721
2049	4.91	.025	-.161	4.609	4.833	3.094	4.028
2054	7.90	.002	.623910	.862690	1.204540	.897047	.328304
2055	9.22	.001	-4.986	-1.405	1.061	-1.777	3.167
2057	10.26	.001	.461900	.732290	.846300	.680163	.194943
2058	14.76	.001	-7.367	-2.813	-1.704	-3.961	2.470
2060	13.14	.001	.348780	.516630	.664420	.509943	.137760
2061	12.25	.001	-10.169	-5.888	-3.697	-6.585	2.974
2063	6.71	.005	.314520	.387100	.502480	.401367	.115732
2064	6.76	.005	-10.734	-8.413	-6.256	-8.468	2.723
2066	12.13	.001	.279190	.367560	.466550	.371100	.085088
2067	12.02	.001	-11.566	-8.846	-6.738	-9.050	2.208
2069	8.61	.002	.305750	.374500	.454980	.378410	.080502
2070	8.50	.002	-10.459	-8.700	-7.031	-8.730	1.860
2072	5.36	.025	14.347	8.172	6.569	9.696	5.611
2074	6.28	.010	9.736	3.893	2.426	5.352	4.878
2075	4.48	.025	25.186	15.498	14.007	18.231	9.064
2081	12.31	.001	-7.171	-3.840	-2.152	-4.387	2.302
2082	8.11	.002	.110171	.176860	.215300	.167444	.059058
2091	4.27	.025	-29.509	-23.055	-24.803	-25.789	5.111
2094	3.40	.050	-27.562	-34.614	-25.817	-29.331	7.984
2096	4.96	.025	-38.573	-33.723	-30.412	-34.236	5.827
2107	4.87	.025	-1.738	-1.179	-1.717	-1.545	.454
2117	8.22	.002	7189.	9507.	6822.	7839.	1606.
2119	5.81	.010	33.930	122.459	-51.200	35.063	113.895
2120	6.48	.010	31.424	53.466	23.971	36.287	19.049
2133	7.17	.005	-.286785	-.251075	.022317	-.171848	.199689
2138	3.39	.050	-.024124	-.020958	-.190290	-.078457	.166336
2141	5.56	.010	-.315165	-.034911	-.311170	-.220415	.215533
2142	5.37	.025	-.151693	.108788	.209793	.055629	.254526
2151	4.83	.025	-.186263	-.073565	.192201	.101633	.218437
2155	4.03	.050	.184360	-.030375	.124211	.092732	.174461
2166	4.37	.025	.502510	.628560	.422300	.517790	.157302
2170	4.07	.050	.279173	.021236	.182274	.160894	.204247
2181	4.23	.050	-.280066	-.045746	-.319933	-.215248	.227883
2200	3.36	.050	62.642	23.113	49.280	45.012	34.711
2203	3.98	.050	-1.974	-5.552	-2.017	-3.181	3.254
2212	4.44	.025	150.475	85.823	64.363	100.220	67.259
2213	4.39	.025	59.575	17.900	51.753	43.076	33.425
2219	3.36	.050	-1.648	-.059	-1.560	-1.069	1.541
2231	9.73	.010	-.363100	-.608710	-.387790	-.453200	.178719
2237	5.00	.025	-.627820	-.945440	-.567293	-.713518	.287224
2239	3.69	.050	-.166403	-.270197	-.066418	-.167673	.167810
2243	6.63	.005	-.096206	-.568220	-.148504	-.270977	.317811
2245	9.01	.001	.000209	-.145178	.066735	-.026078	.114199
2248	9.73	.001	.245434	.570560	.202721	.339572	.203942
2256	3.69	.050	.118048	.261924	.223208	.201060	.122616
2262	4.03	.050	-.334430	-.541760	-.312208	-.396133	.199321
2302	3.59	.050	.339760	.601510	.319730	.420333	.262561
2362	4.19	.050	-2.621	-9.598	-10.268	-7.496	6.540
2368	3.70	.050	-10.586	-14.278	-20.385	-15.083	8.133
2374	4.44	.025	-10.601	-11.685	-15.936	-12.741	4.231
2378	5.24	.025	6060.	1533.	881.	2825.	3895.
2380	5.22	.025	5894.	1420.	835.	2716.	3829.
2394	8.11	.002	-149.046	-211.420	-111.642	-157.369	55.984
2418	8.95	.001	-158.450	-191.390	-133.207	-161.016	30.848
2426	4.04	.050	-26.325	-19.647	-20.792	-22.255	5.620